SEASONAL ABUNDANCE, DISTRIBUTION,

AND POPULATION SIZE-STRUCTURE

OF FISHES IN SAN JUAN RIVER

SECONDARY CHANNELS;

1991 – 1997

David L. Propst and Amber L. Hobbes

Conservation Services Division

New Mexico Department of Game and Fish

Santa Fe, New Mexico

21 February 2000

SAN JUAN RECOVERY IMPLEMENTATION PROGRAM

EXECUTIVE SUMMARY

Between Shiprock, New Mexico and Chinle Creek, Utah, secondary channels are a common feature of the San Juan River. Prior to initiation of the San Juan River Seven-Year Research Program no studies specific to secondary channels had been conducted. As part of the Seven-Year Research Program, research was initiated in 1991 to characterize the fish fauna of San Juan River secondary channels, to discern seasonal-use patterns of secondary channels by common fishes, to evaluate the effects of different flow regimes on common fish species, and to characterize use of secondary channels by rare fishes (roundtail chub, Colorado pikeminnow, and razorback sucker). Summer inventories of secondary channels were initiated in 1991 and spring and autumn inventories began in 1993. Research on secondary channels occurred in Geomorphic Reaches 5, 4, and 3. Flows of 1500 cfs wetted most secondary channels and flows of 2500 cfs inundated almost all.

During spring, when flows were at least 2500 cfs, native flannelmouth sucker and bluehead sucker and nonnative common carp and channel catfish numerically dominated secondary channel fish collections. Small-bodied fishes such as native speckled dace and nonnative red shiner and fathead minnow, were uncommon in spring collections. The sampling technique, raft-mounted electrofishing, was not an effective means of collecting small-bodied fishes. Abundance of flannelmouth sucker was less in 1997 than 1993 in all reaches, but the decline was most apparent in Reach 4. Although abundance evidently declined, mean total length, mean biomass, size-structure, and age-structure were not markedly different in 1997 from that found in 1993. Bluehead sucker abundance was least in 1995 in all Reaches and second greatest in 1997. Neither mean total length nor biomass was appreciably different in 1997 than that found in 1993. In Reach 5, where bluehead was typically most common, there was little change in size- or age-structure, but in Reach 3 (where least common), there was considerable variation in these population attributes among years. In all years in all Reaches, most common carp captured were $\geq$ 400 mm total length and thus adults. Common carp were slightly more common in all reaches in 1997 than 1993, but mean total length and biomass did not change. Abundance of channel catfish in Reaches 5 and 4 was slightly greater in 1997 than 1993, but was considerably greater in Reach 3 in 1997 than 1993. Total biomass, however, was greater in 1993 than 1997 in Reaches 5 and 4. In Reach 3, total biomass was least in 1993, but from1995 through 1997 did not change. Mean total length and biomass declined from 1993 through 1997 in all reaches, but most dramatically in Reaches 5 and 4. Changes in size- and age-structure of channel catfish were also noted; smaller and younger fish were more common in collections in 1997 than 1993. In most years (1994 through 1997) and Reaches flannelmouth sucker was slightly more abundant in secondary channels than the primary channel. Bluehead sucker, however, tended to be more common in the primary than secondary channels. In Reach 5, common carp were more common in secondary channels than primary channel in all years and usually so in

Reach 3. In Reach 4, there was no pattern. In Reaches 5 and 4, channel catfish abundance was usually slightly greater in secondary channels than primary; in Reach 3 in 1995 and 1996 secondary channel abundance was considerably greater. One adult Colorado pikeminnow was collected in a secondary channel in 1994. Razorback suckers (likely stocked individuals) were found in secondary channels in 1995, 1996, and 1997.

Fish species common during spring inventories were usually uncommon or rare in summer collections; most individuals of these species found in summer were young-of-year or juveniles. During summer, abundance of fishes in secondary channels varied considerably from year to year (1991 through 1997). Greatest abundance (Reaches combined) occurred in 1993 and 1995 and least in 1997. Shannon-Wiener Diversity was slightly less in 1997 than 1993. In Reach 5, red shiner was the most abundant species in four years, fathead minnow in two, and bluehead sucker in one. Bluehead sucker (almost all Age 0) summer abundance was greatest in 1995, a high spring runoff year. Speckled dace was usually second- or third-most abundant species. Total fish abundance peaked in 1993 and was least in 1997; Shannon-Wiener Diversity was least in 1991 and changed little from 1993 through 1997. No attribute of spring runoff was significantly related to summer abundance of red shiner, fathead minnow, speckled dace, flannelmouth sucker or channel catfish in Reach 5. Summer abundance of bluehead sucker was, however, significantly and positively related to four of five attributes of spring runoff. Red shiner was the most abundant species in Reach 4 in all years except 1996 when fathead minnow was most abundant. Speckled dace was the second-most common species in five of seven years; it was third-most common in 1994 and sixth-most common in 1996 (a low spring runoff and summer flow year). Total abundance of fishes in Reach 4 peaked in 1993 and 1995 and was least in 1997. Shannon-Wiener Diversity Index declined from 1991 through 1997. Summer abundance of red shiner was fairly strongly, but not significantly, positively related to most attributes of spring discharge in Reach 4. Speckled dace abundance was significantly and positively related to four of five spring runoff attributes. Flannelmouth sucker abundance was strongly, but not significantly, related to days discharge > 5000 cfs and bluehead sucker abundance was most strongly related to days discharge > 8000 cfs. Abundance of fathead minnow and channel catfish was not related to any attribute of spring runoff. Red shiner was the most abundant species in Reach 3 in all years except 1995 and 1996, when fathead minnow was most abundant. Speckled dace was the second-most abundant species in all years except 1994 and 1996; its abundance was least in 1996, a low spring runoff and summer flow year. Similar to Reach 4, total abundance peaked in Reach 3 in 1993 and 1995 (high spring runoff years) and was least in 1997. Shannon-Wiener Diversity declined from 1991 through 1997. Summer abundance of red shiner was significantly, and positively, related to days spring discharge >5000 cfs. Speckled dace and bluehead sucker abundance was significantly, and positively, related to four of five spring runoff attributes. Summer abundance of flannelmouth sucker was most strongly related to days discharge > 5000 cfs. No attribute of spring runoff was related to summer abundance of fathead minnow or channel catfish. Neither Colorado pikeminnow nor razorback sucker was collected in secondary channels during summer.

Fish species common in summer collections were also common in autumn collections. Plains killifish and western mosquitofish were generally more common in autumn than summer collections. Between 1993 and 1995 total autumn abundance of fishes (Reaches combined) did not change appreciably. Total abundance in 1996 (a low spring runoff and summer flow year) was substantially less than in preceding years. In 1997, total abundance was the lowest of the study. From 1993 through 1996, Shannon-Wiener Diversity declined but increased in 1997 to the second-highest value of the study. Total abundance of fishes in Reach 5 peaked in 1993 and 1996 and was lowest in 1997. Between 1993 and 1995, Shannon-Wiener Diversity changed little, declince in 1996, and was highest in 1997. Red shiner was the most abundant species in autumn collections in Reach 5 in all years, except 1997 (high spring runoff and summer flows) when speckled dace was most abundant. Fathead minnow and specked dace were usually the second- or third-most common species. Flannelmouth sucker and bluehead sucker were rare in 1996, a low spring runoff and summer flow year. Colorado pikeminnow, likely stocked individuals, was the third-most common species in Reach 5 secondary channels in 1997. Roundtail chub was found only in 1997. No attribute of summer discharge was significantly related to any commonly-collected species, except the positive relationship between autumn abundance of western mosquitofish and days discharge < 500 cfs. Attributes indicative of low summer flow were negatively related to autumn abundance of native species. Mean summer discharge was negatively related to red shiner abundance. Between 1993 and 1996, total abundance of fishes in Reach 4 declined slightly, but abundance in 1997 was considerably less than in preceding years. Shannon-Wiener Diversity changed little from 1993 through 1996 and increased slightly in 1997. Red shiner was the most abundant species in all years and fathead minnow or speckled dace were second-most abundant in all years. Neither flannelmouth sucker nor bluehead sucker was common during autumn in Reach 4 secondary channels and bluehead sucker was absent in 1996. Colorado pikeminnow and roundtail chub were found in Reach 4 secondary channels in 1997, but not in preceding years. Elevated summer flows were negatively correlated with summer abundance of nonnative red shiner, fathead minnow, channel catfish (significantly) and western mosquitofish; fathead minnow abundance was significantly, and positively, related to days summer discharge < 500 cfs. Autumn abundance of native flannelmouth sucker, bluehead sucker, and speckled dace were negatively, but not significantly, related to days summer discharge < 500 cfs. Total abundance of fishes in Reach 3 peaked in 1995 and was least in 1997. Shann0n-Wiener Diversity declined from 1993 through 1996, but increased in 1997. Red shiner was always the most abundant species in Reach 3 and fathead minnow or speckled dace were always second- or third-most common, except in 1993 when channel catfish was third-most common. Flannelmouth sucker was uncommon in all years and bluehead sucker was absent in 1993. Colorado pikeminnow and roundtail chub were found in 1997. No attribute of summer discharge was significantly related to autumn abundance of any commonly collected species. Speckled dace abundance was negatively related to days discharge < 500 cfs.

In most years (1993 through 1997), summer abundance of fishes was usually greater in summer than autumn; in Reaches 5 and 4 differences were substantial. Between summer and autumn (years combined) abundance differences were typically

significant. For red shiner, seasonal abundance differences were not significant, but differences among years were. Seasonal, reach, and annual comparisons did not yield significant differences for fathead minnow. Seasonal and annual (reaches combined) differences in speckled dace abundance were significant as was that among years (seasons combined). Flannelmouth sucker abundance relationships were similar to those for speckled dace. Only annual comparisons (reaches combined) of bluehead sucker abundance yielded significant differences. Abundance of western mosquitofish was significantly different among years (reaches or seasons combined). Abundance of red shiner, fathead minnow, flannelmouth sucker, and speckled dace generally declined (both summer and autumn) from 1993 through 1997. Abundance of bluehead sucker and western mosquitofish were variable with no evident pattern.

Total species abundance was not a good predictor of total autumn abundance. However, summer abundance of fathead minnow, speckled dace, flannelmouth sucker, bluehead sucker, and western mosquitofish was a good predictor of their autumn abundance. Autumn abundance of red shiner and channel catfish was not related to their summer abundance.

An array of biotic and abiotic factors influenced the seasonal abundance of fishes in secondary channels of the San Juan River. Elevated flows during spring runoff made most secondary channels accessible to all fish residents of the river, particularly large-bodied individuals. Large-bodied fishes may enter secondary channels to forage, spawn, and avoid higher velocity water of the primary channel. Habitat preferences and life history strategies likely influenced the longitudinal abundance distribution of large-bodied fishes in secondary channels. The rarity of Colorado pikeminnow and razorback sucker in secondary channels during spring was likely more a consequence of their overall rarity rather than avoidance of secondary channels. During summer and autumn, fish assemblages of secondary channels are numerically dominated by small-bodied fishes and young of large-bodied fishes. Among these species, nonnative fishes were typically the most abundant. There was generally a positive relationship between summer abundance of several common species, including red shiner, and elevated spring discharge. Although a natural flow regime was mimicked, spring flows during the study were never as high as occurred in some years prior to completion of Navajo Dam. Thus, elevated spring flows evidently were not sufficient to displace some nonnative species, as documented in several other southwestern systems having a natural hydrograph. Elevated flows during summer, however, generally had negative effects on autumn abundance of nonnative fishes and positive or no effect on native fishes. Abundance of all commonly collected species was less in 1997 than in 1993. The low spring runoff and low summer and autumn flows of 1996 depressed the abundance of all species, native and nonnative. Abundance of most increased slightly in 1997 with higher spring runoff and higher summer and autumn flows, but not to levels found prior to 1996. Although the abundance of most species changed with mimicry of a natural hydrograph, it is likely changes will continue as flows continue to mediate species relationships and interactions and habitats change in response to a mimicked natural hydrograph.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SEASONAL ABUNDANCE, DISTRIBUTION,

AND POPULATION SIZE-STRUCTURE

OF FISHES IN SAN JUAN RIVER

SECONDARY CHANNELS,

1991 – 1997

David L. Propst and Amber L. Hobbes

Conservation Services Division

New Mexico Department of Game and Fish

Santa Fe, New Mexico

INTRODUCTION

For large portions of its course through northwestern New Mexico and across southeastern Utah, the San Juan River is restricted to a single channel. The reach between Shiprock, New Mexico and Chinle Creek, Utah is, however, characterized by considerable braiding with much of the water in a primary channel and lesser amounts in secondary channels. Some secondary channels carry water throughout the year, regardless of discharge, but others are wetted mainly during spring runoff and following summer storms. Secondary channels vary considerably in volume of water that passes through each, their length, and structural complexity. As a result of constantly changing physical attributes (particularly degree of inundation), the fish assemblages of secondary channels may be expected to vary.

No historical ichthyofaunal inventories were made of the San Juan River in the reach having extensive braiding (Shiprock to Chinle Creek), but the fish fauna consisted of at least six warmwater species (Tyus et al., 1982; Platania, 1990). Two other native San Juan River fishes (Colorado River cutthroat trout, *Oncorhynchus clarki pleuriticus*, and mottled sculpin, *Cottus bairdi*) may have seasonally occurred in braided portions of the river. Native fishes in the braided reach were three cyprinids (roundtail chub, *Gila robusta*; Colorado pikeminnow, *Ptychocheilus lucius*; and speckled dace, *Rhinichthys osculus*) and three catostomids (flannelmouth sucker, *Catostomus latipinnis*; bluehead sucker, *Catostomus discobolus*; and razorback sucker, *Xyrauchen texanus*). Each of these species presumably used habitats provided by secondary channels.

Since settlement by Europeans of the San Juan basin, at least 19 nonnative fish species have been collected in the San Juan River (Platania, 1990), and six (common carp, *Cyprinus carpio*; red shiner, *Cyprinella lutrensis*; fathead minnow, *Pimephales promelas*; channel catfish, *Ictalurus punctatus*; plains killifish, *Fundulus zebrinus*, and western mosquitofish, *Gambusia affinis*) are seasonally common to abundant in the in the San Juan River downstream of its confluence with the Animas River. Each of the latter nonnative species is seasonally common in secondary channels and each may negatively interact with native fishes. Interactions may be via predation (channel catfish, red shiner, and western mosquitofish;), competition for habitat (fathead minnow and plains killifish), or disturbance (common carp) (Gido and Propst, 1999; Brandenburg and Gido, 1999; Brooks et al., 2000).

A key premise of the San Juan River Seven Year Research Program was that mimicry of the natural hydrograph, including elevated spring flows, was essential to recovery of federally protected Colorado pikeminnow and razorback sucker and conservation of other native fish species in the San Juan River. This premise was based, in part, on the hypothesis that a dynamic natural hydrograph with elevated spring flows maintains essential habitats (e.g., spawning bars) for native fishes. The premise was also based in the hypothesis that a natural hydrograph diminishes or suppresses the abundance of nonnative fish species.

This study was undertaken to characterize the fish fauna of San Juan River secondary channels, to discern seasonal-use patterns of secondary channels by common fishes, to evaluate the effects of different flow regimes on common fish species, and to characterize use of secondary channel habitats by rare fishes. Among the objectives of the San Juan Recovery Implementation Program Long Range Plan, this study provides information to achieve:

5.2.5. Determine and monitor habitat use of endangered and other native fishes.
5.3.1. Identify and characterize the historic and current fish species community structure.
5.3.2. Determine the status and trends of the resident fish species.
5.3.3. Determine the life history of endangered and other native fish species and relationships to all other resident fish species.
5.3.4. Characterize fish species community responses to different annual flow regimes.
5.3.5. Identify limiting factors for the endangered and other native fishes.
5.4.1. Characterize distribution and abundance of nonnative fish species.
5.4.2. Identify and characterize habitats used by nonnative fish species and effects on native fish species habitat use.
5.4.3. Characterize the response of nonnative fish species to varying flow regimes and recommend flows that minimize or eliminate interactions with native fish species.
5.7.2. Develop and maintain a standardized database for storage and retrieval of biotic and abiotic data.
5.7.3. Review and revise research activities to further define needs of and threats to endangered and other native fish species.
5.7.4. Evaluate and refine recovery actions, as necessary, to accomplish recovery Goals.

STUDY AREA

The San Juan River is a major tributary of the Colorado River and drains 99,200 km^2 in Colorado, Utah, Arizona, and New Mexico. From its origins in the San Juan Mountains of southwestern Colorado at elevations exceeding 4,250 m, the river flows westward for about 570 km to the Colorado River. The major perennial tributaries to the San Juan River are Navajo, Piedra, Los Pinos, Animas, LaPlata, and Mancos rivers and McElmo Creek. In addition, there are numerous ephemeral arroyos and washes contributing little total flow but large sediment loads.

Navajo Reservoir, completed in 1963, impounds the San Juan River, isolating the upper 124 km of river and partially regulates downstream flows. The completion of Glen

Canyon Dam and subsequent filling of Lake Powell in the early 1980s inundated the lower 87 km of river, leaving about 359 km of river between the two reservoirs.

From Navajo Dam to Lake Powell, the mean gradient of the San Juan River is 1.67 m/km. Locally, the gradient can be as high as 3.5 m/km, but taken in 30 km increments, the range is from 1.24 to 2.41 m/km. Between the confluence of the San Juan River with Lake Powell and the confluence with Chinle Creek, about 20 km downstream of Bluff, Utah, the river is canyon-bound and restricted to a single channel. Upstream of Chinle Creek, the river is multi-channeled to varying degrees with highest density of secondary channels occurring between Hogback Diversion, about 13 km east of Shiprock, New Mexico, and Bluff, Utah. The reach of river between Navajo Dam and Farmington, New Mexico is relatively stable with predominantly embedded cobble substrate and few secondary channels. Below the confluence with Animas River, the channels is less stable and more subject to floods from the unregulated Animas River. Between Farmington and Shiprock cobble substrate becomes mixed with sand to an increasing degree with distance downstream, resulting in decreasing channel stability.

FISH ASSEMBLAGES OF SAN JUAN RIVER

SECONDARY CHANNELS DURING SPRING

1993 – 1997

INTRODUCTION

During 1991 and 1992 spring ichthyofaunal inventories of the San Juan River between Shiprock and Sand Island, no effort was made to segregate sampling of secondary channels from the overall sampling effort. It was evident, however, there were substantial differences in the habitats provided by secondary and primary channels. Many secondary channels were narrow, shallow, and shaded whereas the primary channel was not shaded (except along some shorelines), often deep, and broad. The sampling protocol at that time did not enable determination of differences, or lack, in species assemblages of secondary and primary channels. Accordingly, in 1993 the adult sampling protocol was modified to segregate sampling of primary and secondary channels. The New Mexico Department of Game and Fish assumed lead responsibility for sampling secondary channels during spring ichthyofaunal surveys.

Objectives of the Secondary Channels Ichthyofaunal Inventory were:

1). Characterize the type of extent of secondary channels in the San Juan River;
2). Characterize the faunal assemblages of secondary channels;
3). Determine seasonal use patterns of secondary channels by target species; and
4). Relate habitat use and availability of secondary channels to flow levels.

This chapter addresses Objectives 1, 2 (in part), and 3 (in part) during spring.

STUDY AREA

Spring inventories of San Juan River secondary channels were conducted from near Hogback to Chinle Creek (Figure 1). Attributes of some secondary channels during the spring were at least superficially similar to those of the adjacent primary channel in that they were comparatively wide (>20 m), had a mixture of general habitat types (e.g., runs, pools, and riffles), and moderately rapid water velocity (0.5 to 1.0 m/sec). Many secondary channels, however, were quite different in many attributes from the primary channel. Secondary channels were often narrow with dense, overhanging vegetation (Russian olive and tamarisk), mainly run habitat with pools around instream obstructions (root masses and boulders), and a few shallow riffles. Water velocity was frequently less than that of the primary channel and undercut banks were common. Average depths of most secondary channels were less than that of the primary channel and maximum depths rarely were as great as depths commonly found in the primary channel. Substrates varied among silt, sand, gravel, and cobble, with sand and cobble being the most common substrates. In low-gradient, shallow secondary channel reaches, silt was the predominant substrate. Near cliffs, large boulders were often in the channel. Secondary channel terraces were typically vegetated (annuals and cottonwood and salt cedar seedlings); during high flows these terraces were often inundated.

The mouths of secondary channels were typically narrow, steep gradient riffles, and surrounded by large debris piles. Flow into some secondary channels was "controlled" by debris berms. After the initial plunge, secondary channel gradient diminished, width increased, and water velocity slowed. The debouchements of secondary channels were sometimes broad, shallow, and sand-bottomed but others were
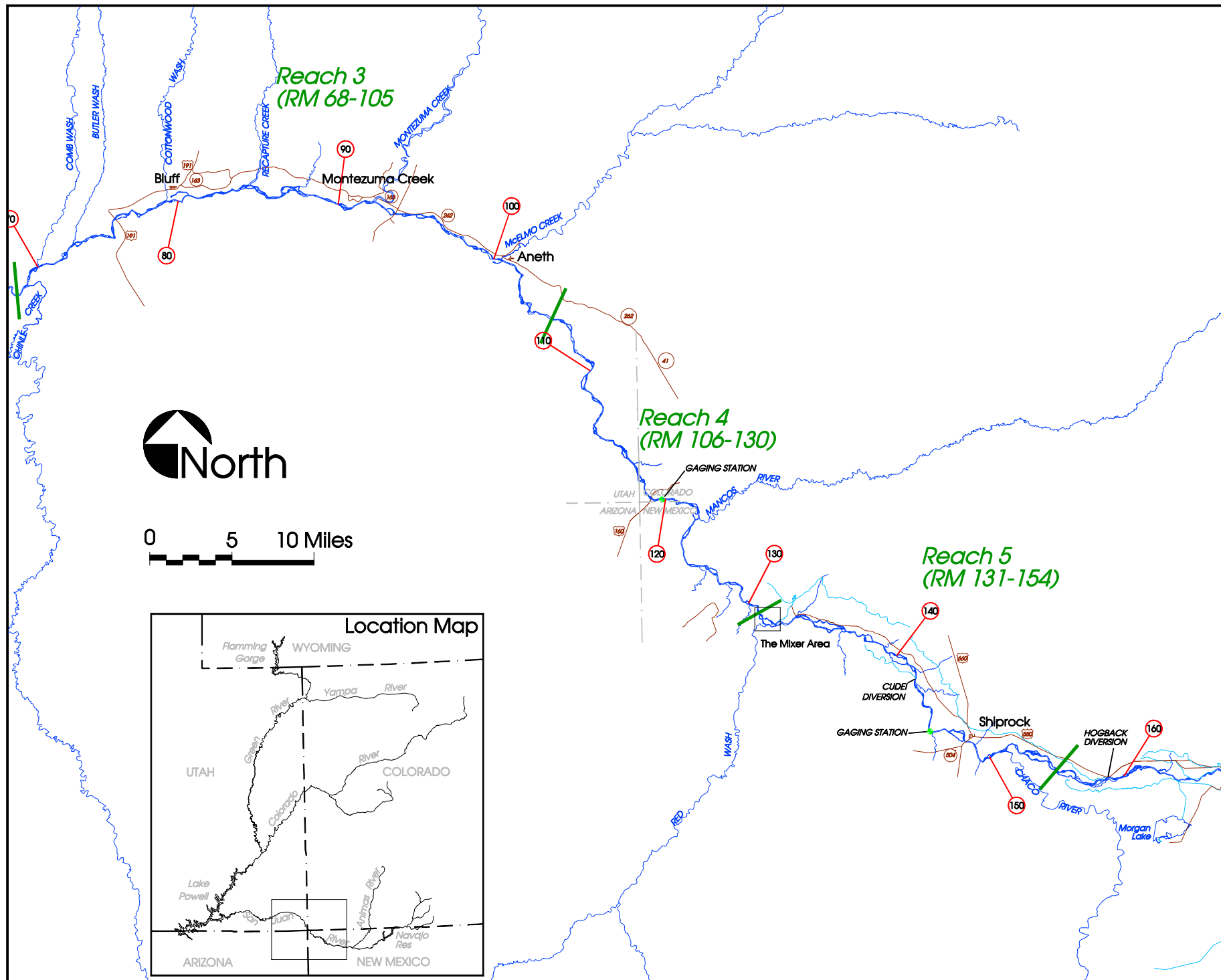
narrow, deep cuts through floodplain terraces of mixed composition (typically sand and cobble). Islands were present in some secondary channels.

At the time of spring inventories, most secondary channels had sufficient flow (minimum depth ca. 0.4 m) to enable passage with electrofishing rafts. Deposition of large woody debris, rocks, and sand during flow recession periods choked the mouths of some secondary channels. Subsequent elevated flows sometimes eroded the berms or, depending on flow volume and position of secondary channel mouth, added to berms. Thus, some secondary channels that were sampled in one spring were impassable in a subsequent year or years and were therefore not sampled.

During the five-year study, spring runoff varied considerably from a low in 1996 (peak never exceeded 4000 cfs) to a high of about 11000 cfs in 1997 (Figure 2). Lowest flow during spring inventories was in 1997 (about 1200 cfs) and the highest was in 1993 when discharge was about 6000 cfs.
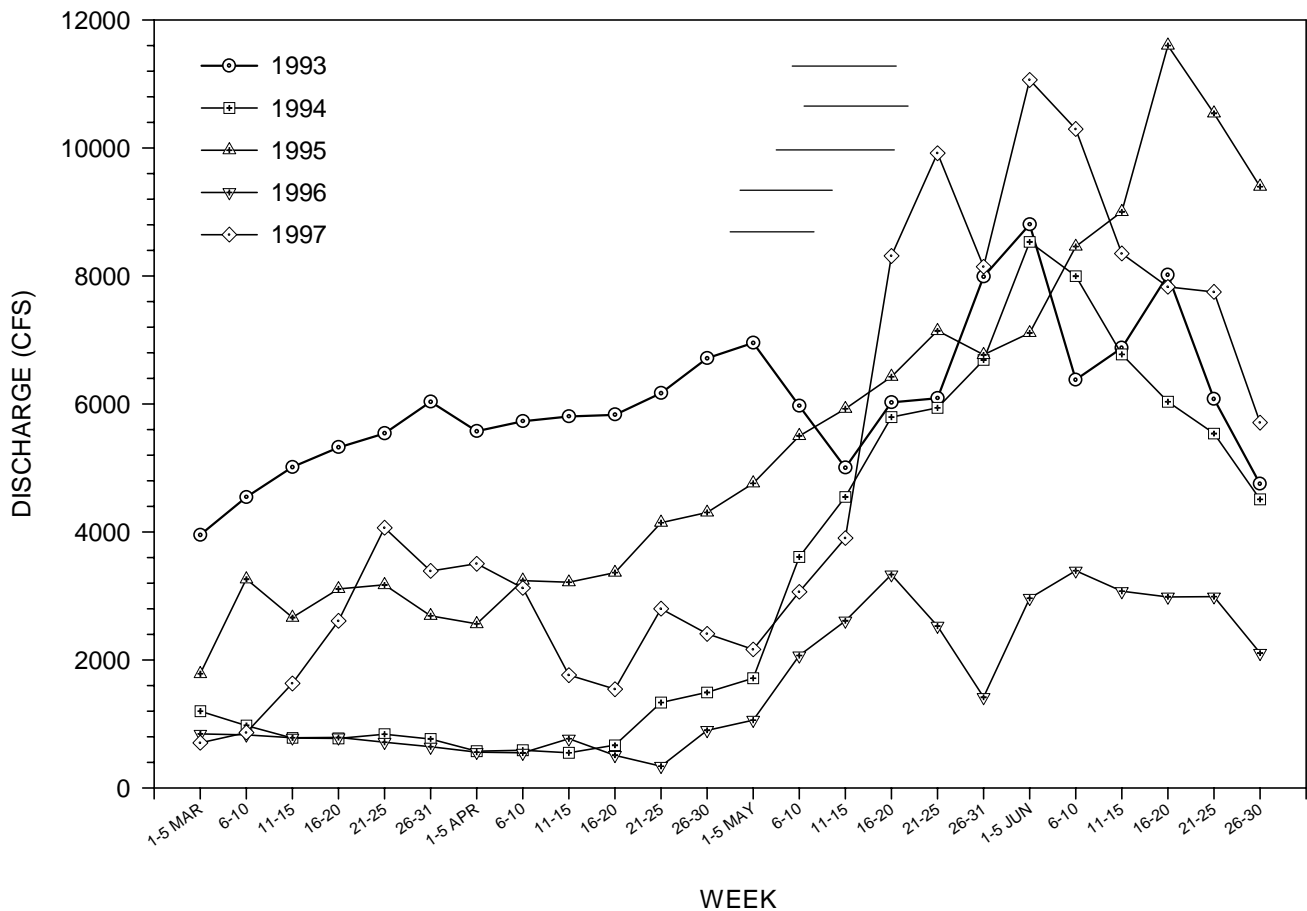
Figure 2. Mean weekly discharge (cfs) of the San Juan River during spring runoff. Horizonal lines with arrows indicate the dates of secondary channel inventories each year.

8

METHODS

Initial identification of secondary channels was done by examination of aerial photographs (1: 12000) taken on 28 May 1988 by U.S. Bureau of Reclamation. Mean daily discharge at time of aerial photography was 1610 cfs (Shiprock gage). The visual standard for classification as a secondary channel was that in braided reaches, the channel with the greatest wetted width was the primary channel and all others were secondary channels. It was assumed that the widest channel carried the greatest volume of water; based on subsequent experience, this almost always the case. An arbitrary scheme was used to classify secondary channels. Type I channel was $\leq$ 1 km long and had $\geq$ 25 and $\leq$ 50 % of total discharge, Type II was $\leq$ 1 km long and had < 25 % of total discharge, Type III was > 1 km long and had $\geq$ 25 and $\leq$ 50 % of discharge, and Type IV was > 1 km long and had < 25 % of total discharge.

Sampling of San Juan River secondary channels occurred each May from 1993 through 1997. Sampling was conducted in Geomorphic Reaches 5 (RM 154 through 131), 4 (RM 130 through RM 106), and 3 (RM 105 through RM 68)(Bliesner and Lamarra, 2000). Channels < 100 meters long and carrying < 50% of the river's discharge were not treated as secondary channels. Secondary channel flow volume was visually estimated as a percent of total discharge. Sampling was conducted when flows were greater than winter base flows (normally between 600 and 800 cfs) but less than the annual spring peak (usually > 5000 cfs). Peak spring runoff occurred about one month after spring sampling. Regardless of specific level, flows were sufficient to allow passage of rafts with electrofishing gear (5000 watt generator, with bow anode and stern cathode) through most San Juan River secondary channels between RM 154 and RM 68. In secondary channels of sufficient width (about 4 m), the raft was positioned perpendicular (bow towards shore) to the shore as the current carried it downstream. The particular shore sampled often changed within a secondary channel because of instream obstructions and overhanging vegetation. In narrow channels (< 4 m), the raft was pointed downstream in mid-channel. The netter, on the bow deck, attempted to net all fish, regardless of size or species, stunned by electrofishing gear. Electrical output was between 3 and 4 amps. Captured fish were placed in a live well.

All fish captured were identified and counted. All specimens of commonly collected large-bodied (common carp, flannelmouth sucker, bluehead sucker, and channel catfish) and rare fishes (roundtail chub, Colorado pikeminnow, and razorback sucker) were weighed ($\pm$ 1 g if < 249 and $\pm$ 5 g if > 250 mm TL), and measured ($\pm$ 1 mm TL and SL) at the end of each sampled secondary channel. Native fishes were returned to the river alive. Depending on other ongoing studies, nonnative fishes were returned alive to river, retained as voucher specimens, sacrificed for food habits studies, or removed for nonnative suppression studies. Elapsed time electrofishing (seconds) was recorded for each secondary channel. If a captured fish had a Floy tag, the tag number and specimen TL, SL and weight were recorded.

San Juan River discharge data were obtained from the USGS Shiprock gage (# 09368000). Water temperature (C°), dissolved oxygen (mg/l), conductivity (μmho/cm) were measured at the downstream end of each sampled secondary channel. Notes on habitat, fish aggregations, and general conditions were recorded for each sampled secondary channel. Although flow level determined, in part, which secondary channels were sampled, the number sampled per Geomorphic Reach did not vary greatly from year to year. Forty-four secondary channels were sampled in 1994, 1995, and 1996, 40 in 1993, and 36 in 1997. In Geomorphic Reach 5, 9 to 12 secondary channels were sampled each year, 14 to 18 in Reach 4, and 11 to 21 in Reach 3.

Fish data were compiled by Geomorphic Reach. If a secondary channel was in two Geomorphic Reaches, its data were included with that of the Reach in which a majority of its linear length occurred. Abundance was defined as the number of fish (total or by species) captured per minute elapsed time electrofishing. Six-letter codes (first three letters of genus and first three letters of species) were used to identify species in tables and figures. Commonly collected species were aged following the classifications of the Upper Basin (D.Ryden, pers. comm.), except that the Upper Basin juvenile age-class was divided into juvenile and sub-adult classes for San Juan River secondary channel fishes. Thus, total-length ranges for San Juan River fishes were Age 0 or young-of-year (YOY) $\leq$ 75 mm (flannelmouth sucker, bluehead sucker, common carp, and channel catfish), juvenile = 76 to 200 mm (flannelmouth sucker) or 76 to 175 mm (bluehead sucker, common carp, and channel catfish), sub-adult = 201 to 400 mm (flannelmouth sucker) or 176 to 300 (bluehead sucker, common carp, and channel catfish), and adult = > 401 (flannelmouth sucker) or >301 (bluehead sucker, common carp, and channel catfish).

All species collected were considered in characterizing overall changes, or lack, in secondary channel fish assemblages. Only frequently and commonly collected fishes were used in detailed comparisons among and within species by Geomorphic Reach and year. These comparisons were restricted to flannelmouth sucker, bluehead sucker, common carp, and channel catfish. Several species, such as speckled dace and red shiner, were frequently collected; however, their numbers were usually low and these species were not used for most analyses. The sampling technique (boat-mounted electrofishing gear) precluded unbiased sampling of these species.

Abundance (number of specimens per minute elapsed time electrofishing) and biomass data for common carp, flannelmouth sucker, bluehead sucker, and channel catfish captured in the primary channel during concurrent inventories were provided by the USFWS Grand Junction office. Only data from primary channel designated miles (every fifth mile; see Ryden, 2000 for details) were used in comparisons with secondary channels. Primary and secondary channels were grouped by Geomorphic Reach. Mean biomass of each species was calculated by total weight of species/number of species specimens.

Linear regression analysis was used to determine if flow volume at time of sampling influenced sampling efficiency. Coefficients of variation (CV) were calculated for several repeatedly measured attributes (e.g., abundance). Friedman's test and Kendall's coefficient of concordance (Zar, 1984) were used to evaluate the abundance rank of fishes (all species except those collected once or twice during the study) in each Geomorphic Reach across years. Analysis of variance (ANOVA) was used to compare differences in total abundance among years and Reaches. Changes in abundance, mean total length, total biomass, and mean biomass (per year and Geomorphic Reach) of individual species were also evaluated with ANOVA. Analysis of variance was used to compare primary and secondary channel data (abundance and mean biomass). The Kolomogorov-Smirnov goodness of fit test was used to sequentially compare the size-structure (25 mm length-classes) of commonly collected fishes. The significance threshold for all tests was $\leq$ 0.05.

RESULTS

Secondary Channel Classifications

The scheme to classify secondary channels by length and proportion of total discharge provided a convenient means of generally describing secondary channels. However, for analytical purposes, the

scheme was not satisfactory. Few channels were classified as Type I or III. The rarity of these types (typically fewer than five of either were present during any inventory) rendered comparisons of their fish assemblages to those of common types (II and IV) problematic and statistically unsound. In addition, comparison of fish assemblages among channel types did not help elucidate or clarify similarities and dissimilarities. Therefore the Geomorphic Reaches of Bliesner and Lamarra (2000) were used to group data for analyses.

Water Quality

During most years, measured water quality parameters were similar from the most-upstream through the most-downstream secondary channels. Water temperature tended to increase slightly in a downstream direction (Figure 3). Water temperature, at time of inventory, was highest in 1996 (a low spring runoff year) and lowest in 1995 (a relatively high spring runoff year). Dissolved oxygen changed little among secondary channels in all years except 1994 (Figure 4). Mean secondary channel dissolved oxygen was lowest in 1996 and highest in 1993. From 1993 through 1996, specific conductance did not change appreciably among secondary channels (except downstream of RM 95 in 1995) and mean specific conductance was between 250 and 293 μmhos/cm (Figure 5). In 1997, specific conductance increased in a downstream direction, varied among secondary channels, and generally was higher than during preceding years.

Spring Secondary Channel Fish Assemblages

San Juan River secondary channel fish assemblages were inventoried in early to mid May from 1993 through 1997. Sampling was conducted in Geomorphic Reaches 5 through 3 (RM 154 – 68). A total of seventeen fish species and one hybrid form (Table 1) was collected during the study period. The greatest number of species was found in 1996 (four native and nine nonnative) and the fewest in 1993 and 1997 (three native, six nonnative and four native, five nonnative, respectively). Native flannelmouth sucker was the most common fish species in secondary channels in all years (Table 2). The abundance of other species, however, was variable among years. Bluehead sucker was the second-most common fish in 1993, but it was less abundant in subsequent years. Common carp was third-most common in 1993 and 1997 and second-most common in 1994 through 1996. Channel catfish was fourth and fifth-most common in 1993 and 1994, but its abundance increased, relative to other species, from 1995 through 1997. Speckled dace varied from the fourth to seventh most common species. Red shiner and fathead minnow abundance likewise varied among years. One Colorado pikeminnow was
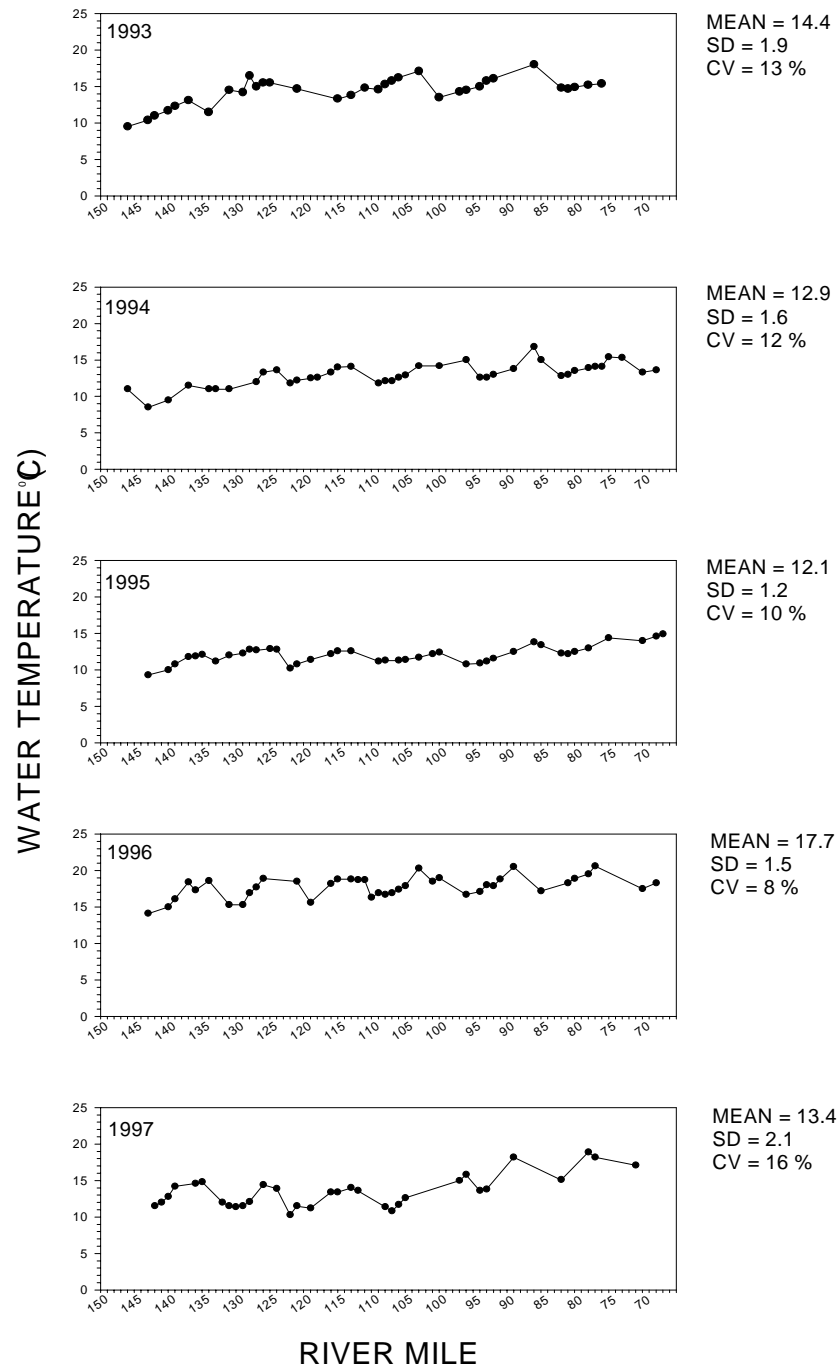
Figure 3. Temperature (°C) of San Juan River secondary channels during spring inventories, 1993 - 1997.

12
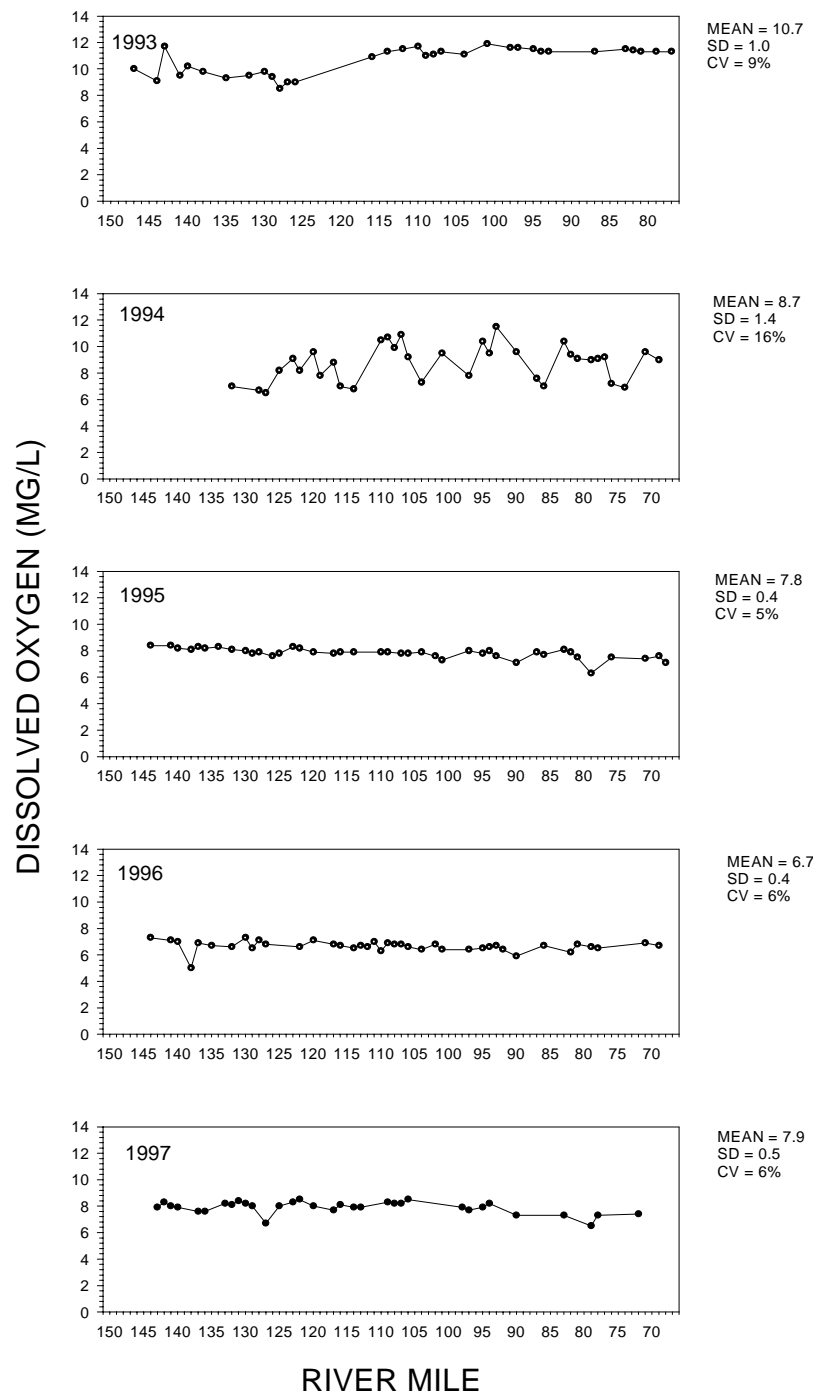
Figure 4. Dissolved oxygen (mg/l) of San Juan River secondary channels during spring inventories, 1993 - 1997.

13
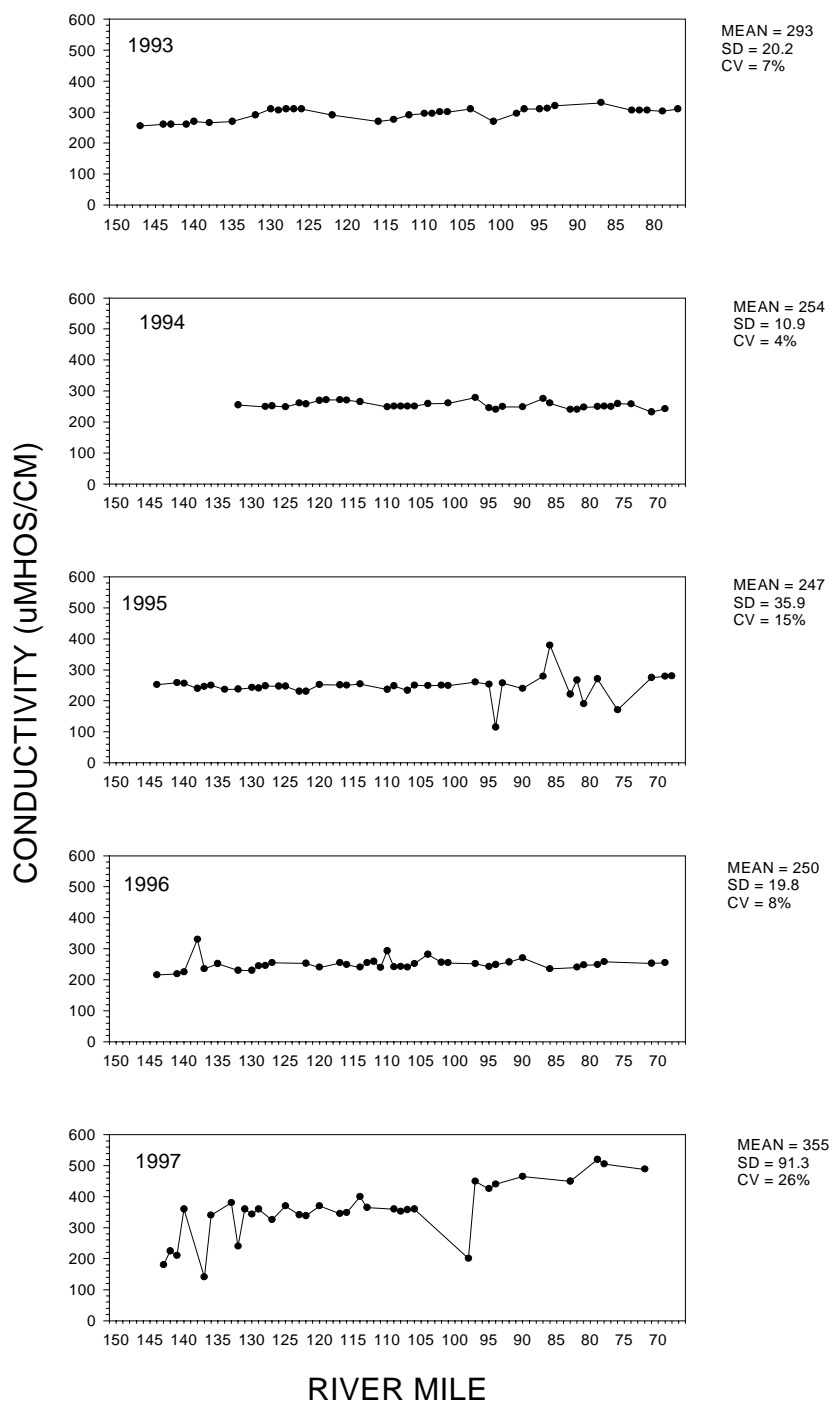
Figure 5. Conductivity (umhos/cm) of San Juan River secondary channels during spring inventories, 1993 - 1997.

14

Table 1. Occurrence of fishes in San Juan River secondary channels during spring, 1993 – 1997.Acronyms for each species derived from first three letters of genus and first three letters of species. I = introduced and N = native,

COMMON	SPECIES SCIENTIFIC	ACRONYM	STATUS	1993	1994	1995	1996	1997
Common carp	*Cyprinus carpio*	CYPCAR	I	X	X	X	X	X
Red shiner	*Cyprinella lutrensis*	CYPLUT	I	X	X	X	X	X
Fathead minnow	*Pimephales promelas*	PIMPRO	I	X	X	X	X	
Colorado pikeminnow	*Ptychocheilus lucius*	PTYLUC	N		X			
Speckled dace	*Rhinichthys osculus*	RHIOSC	N	X	X	X	X	X
Flannelmouth sucker	*Catostomus latipinnis*	CATLAT	N	X	X	X	X	X
Bluehead sucker	*Catostomus discobolus*	CATDIS	N	X	X	X	X	X
Flannelmouth x bluehead sucker	*C. latipinnis* x *C. discobolus*	LATDIS		X	X	X	X	
Razorback sucker	*Xyrauchen texanus*	XYRTEX	N			X	X	X
Black bullhead	*Ameiurus melas*	AMEMEL	I		X	X	X	X
Yellow bullhead	*Ameiurus natalis*	AMENAT	I					X
Channel catfish	*Ictalurus punctatus*	ICTPUN	I	X	X	X	X	X
Rainbow trout	*Oncorhynchus mykiss*	ONCMYK	I	X		X		
Brown trout	*Salmo trutta*	SALTRU	I	X	X			
Plains killifish	*Fundulus zebrinus*	FUNZEB	I				X	
Green sunfish	*Lepomis cyanellus*	LEPCYA	I		X	X	X	
Smallmouth bass	*Micropterus dolomieu*	MICDOL	I				X	
Largemouth bass	*Micropterus salmoides*	MICSAL	I			X	X	
Total Native[1]			5	3	4	3	4	4
Total Nonnative			12	6	7	8	9	5

[1]excluding flannelmouth x bluehead sucker

collected in 1994 and razorback suckers were collected in 1995, 1996, and 1997. Differences in among year abundance rank of the eight most-commonly collected fish species, however, were not significant. Kendall's coefficient of concordance was 0.7995 (Friedman's χ^2 = 27.98, *p*<0.0002).

The greatest number of fish specimens was collected in 1993 and the fewest in 1995. The highest CPUE was in 1993 (3.21 fish/minute) and the lowest in 1995 (2.06 fish/minute). Stream discharge (at time of sampling) did not affect CPUE (r^2 = 0.0013, *p* = .9543) or total number of specimens collected (r^2 = 0.0296, *p* = .7822).

In Geomorphic Reach 5 (RM154 – RM131), the greatest number of fish and species were collected in 1993 (Table 3). Abundance of fishes was also greatest in 1993; in subsequent years abundance did not vary greatly (Figure 6). The fewest species were collected in 1997, but abundance that year was the second-highest during the study in Geomorphic Reach 5. Flannelmouth sucker was the most abundant fish each year, and was often twice or more common than the next most-common species. Common carp was the second-most common species in all years except 1993 when bluehead sucker was second-most common. The abundance rank of other species varied among years;

Table 2. Fish species collected in San Juan River secondary channels (RM 154 – RM 68) during spring inventories, 1993 – 1997. Bold-lettered species were used to calculate Friedman's χ^2 and Kendall's coefficient of concordance (W).

1993		1994		1995		1996		1997	
Species	N	Species	N	Species	N	Species	N	Species	**N**
CATLAT	1127	**CATLAT**	1099	**CATLAT**	815	**CATLAT**	747	**CATLAT**	545
CATDIS	317	**CYPCAR**	158	**CYPCAR**	94	**CYPCAR**	312	**ICTPUN**	250
CYPCAR	123	**CATDIS**	66	**ICTPUN**	79	**ICTPUN**	155	**CYPCAR**	235
RHIOSC	111	**PIMPRO**	65	**RHIOSC**	54	**CYPLUT**	86	**CATDIS**	122
ICTPUN	92	**CYPLUT**	55	**CATDIS**	21	**CATDIS**	74	**RHIOSC**	22
CYPLUT	71	**ICTPUN**	33	**CYPLUT**	12	**PIMPRO**	67	AMENEB	5
PIMPRO	20	**RHIOSC**	28	**CAT X DIS**	4	**RHIOSC**	58	AMEMEL	4
CAT X DIS	9	**CAT X DIS**	6	**PIMPRO**	3	AMEMEL	4	CYPLUT	3
ONCMYK	2	AMEMEL	3	ONCMYK	1	XYRTEX	2	XYRTEX	1
SALTRU	1	PTYLUC	1	AMEMEL	1	CAT X DIS	1		
		SALTRU	1	LEPCYA	1	FUNZEB	1		
		LEPCYA	1	MICSAL	1	LEPCYA	1		
TOTAL N	1873		1516		1086		1508		1187
ABUND.	3.21		2.63		2.06		2.84		2.36

however, changes in abundance rank among years were not significant (Kendall's W = 0.9063; Friedman's χ^2 = 31.59, p<0.00005). Neither Colorado pikeminnow nor razorback sucker was collected in secondary channels in Geomorphic Reach 5 during spring inventories.

Geomorphic Reach 4, in 1993, yielded the greatest abundance (4.087 fish/min) and numerically largest (n = 803) secondary channel spring inventory fish collection during this study (Table 4). In subsequent years, abundance ranged from 2.016 (1997) to 2.738 (1996) (Figure 6). Species richness was greatest (11 species) in 1996 and least in 1995 (5 species). Flannelmouth sucker was the most abundant fish in all years. In 1993 and 1994, bluehead sucker was the second-most abundant species, but nonnative channel catfish was second-most common in 1995 and common carp was in 1996 and 1997. Flannelmouth sucker was always at least three times as abundant as the next common-species. Although the abundance rank of species was variable among years, the differences were not significant (Kendall's W = 0.6114; Friedman's χ^2 = 24.20, p<0.001). One razorback sucker was collected from a Geomorphic Reach 4 secondary channel in 1996.

The greatest number of specimens collected in Geomorphic Reach 3 was obtained in 1994 (N = 649), but the greatest abundance was in 1996 (3.7803 fish/min) (Figure 6 and Table 5). Flannelmouth sucker was numerically the most common fish in all years. Speckled dace was the second-most common species in 1993, common carp in 1994 through 1996, and channel catfish in 1997. Eleven species were collected in 1996, but only 6 in 1997. Rank abundance of species was not different among years of the study (Kendall's W = 0.6865; Friedman's χ^2 = 24.03, p<0.001). One Colorado pikeminnow was collected in a Geomorphic Reach 3 secondary channel in 1994 and one razorback sucker in each 1995, 1996, and 1997.
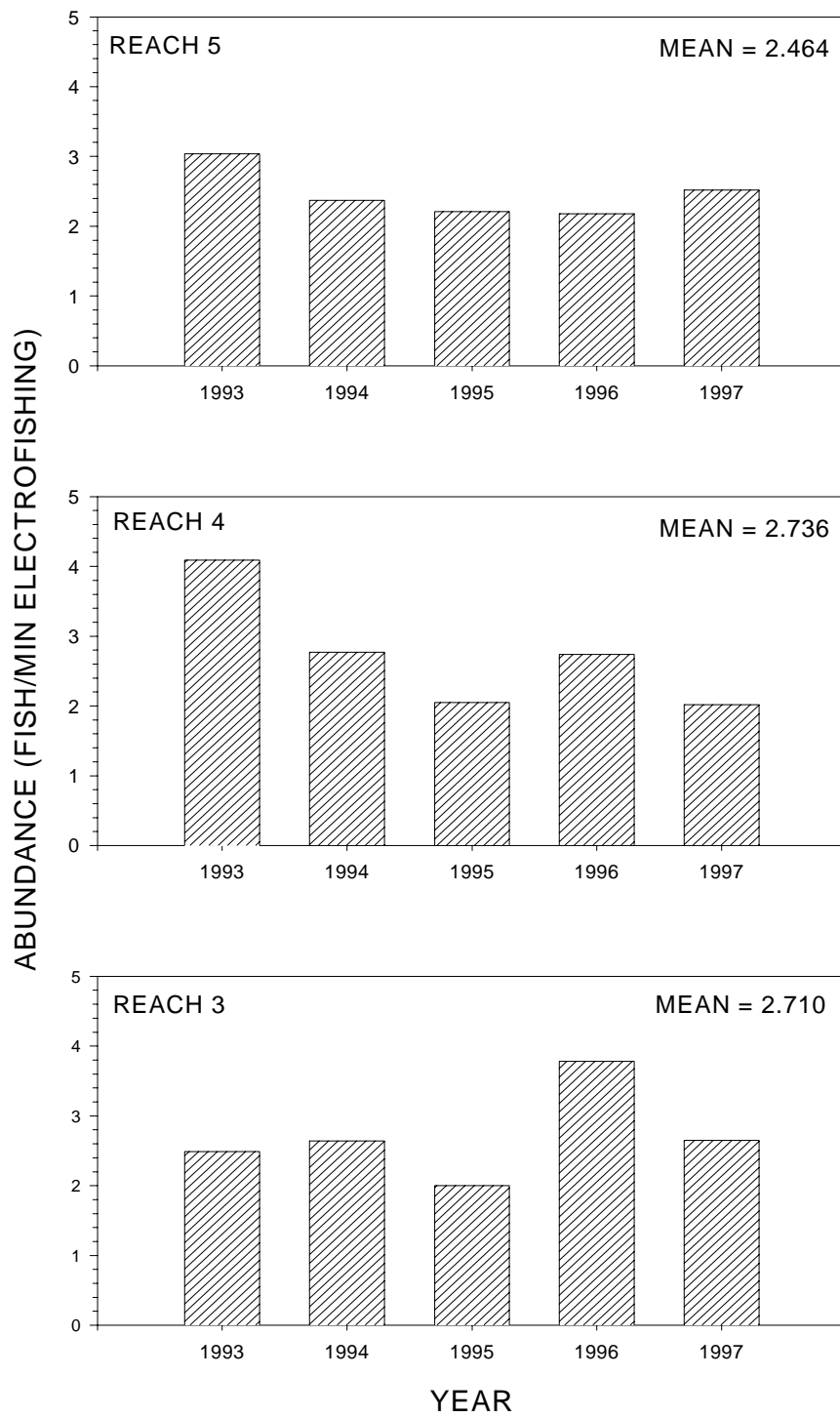
Figure 6. Abundance of fishes in San Juan River secondary channels during spring inventories, 1993 - 1997.

Table 3. Number and abundance (number/minute elapsed electrofishing time) of fishes in San Juan River secondary channels in Geomorphic Reach 5 (RM154 – RM131) during spring, 1993 – 1997.

1993			1994			1995			1996			1997		
SPECIES	N	ABU	SPECIES	N	ABU	SPECIES	N	ABU	SPECIES	N	ABU	SPECIES	N	ABU
CATLAT	314	1.39	CATLAT	258	1.71	CATLAT	177	1.57	CATLAT	186	1.08	CATLAT	167	0.94
CATDIS	211	0.94	CYPCAR	45	0.30	CYPCAR	32	0.28	CYPCAR	79	0.46	CYPCAR	123	0.69
CYPCAR	74	0.33	CATDIS	19	0.13	RHIOSC	16	0.14	CATDIS	43	0.25	CATDIS	71	0.40
ICTPUN	42	0.19	ICTPUN	14	0.09	ICTPUN	14	0.12	PIMPRO	37	0.22	ICTPUN	71	0.40
RHIOSC	22	0.10	RHIOSC	9	0.06	CATDIS	4	0.04	ICTPUN	18	0.10	RHIOSC	9	0.05
CYPLUT	13	0.06	PIMPRO	6	0.04	CYPLUT	4	0.04	RHIOSC	6	0.03	AMENEB	5	0.03
PIMPRO	4	0.02	CYPLUT	4	0.03	ONCMYK	1	0.01	CYPLUT	4	0.02	CYPLUT	1	0.01
LAT x DIS	3	0.01	LAT x DIS	2	0.01	PIMPRO	1	0.01	LAT x DIS	1	0.01			
ONCMYK	1	<0.01												
SALTRU	1	<0.01												
TOTAL N	685			357			249			374			447	
EFFORT	13530			9055			6769			10303			10644	
ABUND	3.04			2.37			2.21			2.18			2.52	

Despite some variation in fish abundance among Geomorphic reaches and across years, these differences were not significant. Two-way ANOVA yielded F = 0.322 ($p = 0.7338$) for among reach comparisons and F = 1.645 ($p = 0.2543$) for across year comparisons.

During spring secondary channel inventories, four species were collected in sufficient numbers to enable comparisons of abundance. Flannelmouth sucker was the most abundant species in all years in all Geomorphic reaches (Table 6). It was most abundant in Geomorphic Reach 4 in all years, but 1997, and least abundant in Geomorphic Reach 5 in all years except 1995. Two-way ANOVA indicated significant differences among reaches (F = 5.669, $p = 0.0292$) and across years (F = 7.906, $p = 0.007$) in flannelmouth sucker abundance.

Abundance of bluehead sucker decreased from Geomorphic Reach 5 through Reach 3 in 1993, 1996, and 1997. Its abundance in Reach 3 was 80%+ less than that in Reach 5 in most years. These differences, however, were not significant (F = 4.249, $p = 0.0553$). Although abundance of bluehead sucker was highest in each reach in 1993, the across years change in its abundance was not significant (F = 3.314, $p = 0.0701$).

Common carp abundance did not vary greatly within each reach across years (F = 2.566, $p = 0.1196$) nor was its abundance different among reaches (F = 1.3856, $p = 0.3043$). It was least common in Reaches 5 and 4 in 1995 and Reach 3 in 1993. In 1996, common carp abundance in Reach 3 was greater than channel catfish and bluehead sucker abundance in all reaches.

Table 4. Number and abundance (number/minute elapsed electrofishing time) of fishes in San Juan River secondary channels in Geomorphic Reach 4 (RM130 – RM106) during spring, 1993 – 1997.

1993			1994			1995			1996			1997		
SPECIES	N	ABU	SPECIES	N	ABU	SPECIES	N	ABU	SPECIES	N	ABU	SPECIES	N	ABU
CATLAT	483	2.46	CATLAT	407	2.26	CATLAT	260	1.63	CATLAT	322	1.59	CATLAT	219	1.13
CATDIS	90	0.46	CATDIS	34	0.19	ICTPUN	23	0.14	CYPCAR	73	0.36	CYPCAR	68	0.35
RHIOSC	68	0.35	CYPLUT	23	0.13	CATDIS	17	0.11	CYPLUT	38	0.19	ICTPUN	47	0.24
CYPLUT	53	0.27	CYPCAR	21	0.12	RHIOSC	13	0.08	ICTPUN	38	0.19	CATDIS	43	0.22
CYPCAR	49	0.25	RHIOSC	14	0.08	CYPCAR	11	0.07	CATDIS	32	0.16	RHIOSC	9	0.05
ICTPUN	39	0.20	PIMPRO	7	0.04	LAT x DIS	2	0.01	RHIOSC	29	0.14	AMEMEL	4	0.02
PIMPRO	15	0.08	LAT x DIS	2	0.01				PIMPRO	10	0.05	CYPLUT	2	0.01
LAT x DIS	5	0.03	ICTPUN	1	0.01				AMEMEL	3	0.01			
ONCMYK	1	0.01	SALTRU	1	0.01				MICSAL	3	0.01			
									XYRTEX	1	<0.01			
									MICDOL	1	<0.01			
TOTAL N	803			500			326			550			392	
EFFORT		11790			10813			9553			12164			11665
ABUND		4.09			2.77			2.05			2.74			2.02

Mean channel catfish abundance was greatest in Geomorphic Reach 3, mainly the consequence of its high abundance in 1996 and 1997. The abundance of channel catfish in Reach 3 in 1997 was greater than that of common carp and bluehead sucker in all reaches. However, neither among reach (F = 1.898, p = 0.2115) nor across years (F = 2.653, p = 0.1120) differences in channel catfish abundance were significant.

Among commonly-collected species, only flannelmouth sucker had a comparatively low abundance coefficient of variation (< 30% in all reaches). All other commonly-collected species had high coefficients of variation (> 50%) in most reaches. The abundance of flannelmouth sucker varied most in Reach 4, bluehead sucker in Reach 5, and common carp and channel catfish in Reach 3.

Table 5. Number and abundance (number/minute elapsed time electrofishing) of fishes in San Juan River secondary channels in Geomorphic Reach 3 (RM15 – RM68) during spring, 1993 – 1997.

	1993			1994			1995			1996			1997		
SPECIES	N	ABU	SPECIES	N	ABU	SPECIES	N	ABU	SPECIES	N	ABU	SPECIES	N	ABU	
CATLAT	330	2.05	CATLAT	434	1.76	CATLAT	378	1.48	CATLAT	239	1.52	CATLAT	159	1.21	
RHIOSC	21	0.13	CYPCAR	92	0.37	CYPCAR	51	0.20	CYPCAR	160	1.02	ICTPUN	132	1.01	
CATDIS	16	0.10	PIMPRO	52	0.21	ICTPUN	42	0.16	ICTPUN	99	0.63	CYPCAR	44	0.34	
CYPCAR	16	0.10	CYPLUT	28	0.11	RHIOSC	25	0.10	CYPLUT	44	0.28	CATDIS	8	0.06	
ICTPUN	11	0.07	ICTPUN	18	0.07	CYPLUT	8	0.03	RHIOSC	23	0.15	RHIOSC	4	0.03	
CYPLUT	5	0.03	CATDIS	13	0.05	LAT x DIS	2	0.01	PIMPRO	20	0.13	XYRTEX	1	0.01	
LAT x DIS	1	0.01	RHIOSC	5	0.02	PIMPRO	2	0.01	CATDIS	4	0.03				
PIMPRO	1	0.01	AMEMEL	3	0.01	XYRTEX	1	<0.01	XYRTEX	1	0.01				
			LAT x DIS	2	0.01	AMEMEL	1	<0.01	AMEMEL	1	0.01				
			PTYLUC	1	<0.01	LEPCYA	1	<0.01	FUNZEB	1	0.01				
			LEPCYA	1	<0.01	MICSAL			LEPCYA	1	0.01				
TOTAL N	401			649			512			593			348		
EFFORT		9682			14775			15364			9412			7876	
ABUND		2.49			2.64			2.00			3.78			2.65	

Table 6. Abundance (fish/minute elapsed electrofishing time) of commonly collected fishes in San Juan River secondary channels during spring 1993 – 1997, New Mexico, Colorado, and Utah. Number below six-letter code indicates Geomorphic Reach. Coefficients of variation (CV) reported as percents.

	SPECIES											
	CATLAT			CATDIS			CYPCAR			ICTPUN		
YEAR	5	4	3	5	4	3	5	4	3	5	4	3
1993	1.39	2.46	2.05	0.94	0.46	0.10	0.33	0.25	0.10	0.19	0.20	0.07
1994	1.71	2.26	1.76	0.13	0.19	0.05	0.30	0.12	0.37	0.09	0.01	0.07
1995	1.57	1.63	1.48	0.04	0.11	0.00	0.28	0.07	0.20	0.12	0.14	0.16
1996	1.08	1.59	1.52	0.25	0.16	0.03	0.46	0.36	1.02	0.10	0.19	0.63
1997	.94	1.13	1.21	0.40	0.22	0.06	0.69	0.35	0.34	0.40	0.24	1.01
MEAN	1.338	1.814	1.604	0.352	0.228	0.048	0.412	0.230	0.406	0.180	0.156	0.388
SD	0.324	0.540	0.317	0.355	0.136	0.037	0.171	0.132	0.360	0.129	0.089	0.418
CV	24.2	29.8	19.8	100.9	59.7	77.1	41.5	57.4	88.7	71.7	57.1	107.7

Population dynamics

Flannelmouth sucker—Size-structure of the flannelmouth sucker population in Geomorphic Reach 5 did not vary greatly among years (Figure 7). Sequential comparison of the size-structure of specimens in annual Reach 5 collections did not yield any significant differences (Table 7). The spring sampling methodology precluded efficient collection of young-of-year or Age-1 (YOY, $\leq$ 120 mm TL) specimens and few were taken. Sub-adults (200 to 399 mm TL) were typically the most common age-class and adults ($\geq$ 400 mm TL) were usually the second-most common (Figure 8). Although the absolute number and abundance of flannelmouth suckers collected declined from 1993 through 1997, mean total length remained about the same (Figure 9).

In Geomorphic Reach 4, the size-structure of flannelmouth sucker samples did not vary greatly from year-to-year, until 1997 (Figure 10). Prior to 1997, fish between 225 and 299 mm TL were comparatively common, but in 1997 few fish in this size-range were collected. Observed differences, however, were not significant (Table 7). Age-class abundance varied substantially from year –to-year (Figure 11). For example, juveniles were 27 % of the collection in 1995, but only 7 % in 1997. In most years, sub-adults were the numerically largest age-class but in 1997 adults were the largest age-class in the collection. Mean total length varied slightly from 1993 through 1996, but increased substantially in 1997 (Figure 9). While mean total length was similar for most years, density of flannelmouth sucker steadily declined from 1993 through 1997.

Table 7. Results of Kolomogorov-Smirov (D_{max}) sequential comparisons of size-structure of flannelmouth suckers in San Juan River secondary channel collections, spring 1993 – 1997.

	YEARS	D_{MAX}	SIGNIFICANCE
GEOMORPHIC REACH 5	93 – 94	0.1775	NS
	94 – 95	0.1818	NS
	95 – 96	0.1364	NS
	96 – 97	-0.2273	NS
GEOMORPHIC REACH 4	93 – 94	0.2273	NS
	94 – 95	0.1818	NS
	95 – 96	-0.2473	NS
	96 – 97	-0.1436	NS
GEOMORPHIC REACH 3	93 – 94	0.1364	NS
	94 – 95	0.2273	NS
	95 – 96	0.2745	NS
	96 – 97	-0.1855	NS

Size-structure of flannelmouth sucker collections in Reach 3 varied from 1993 through 1997 (Figure 12). In 1995, for example, a comparatively large number of individuals (ca. 23 % of collection) in two length-classes (150 to 200 mm) were collected. The 1997 collection, in contrast to all others, had a large proportion (ca. 42 %) of individuals > 375 mm TL. These observed changes in size-structure, however,
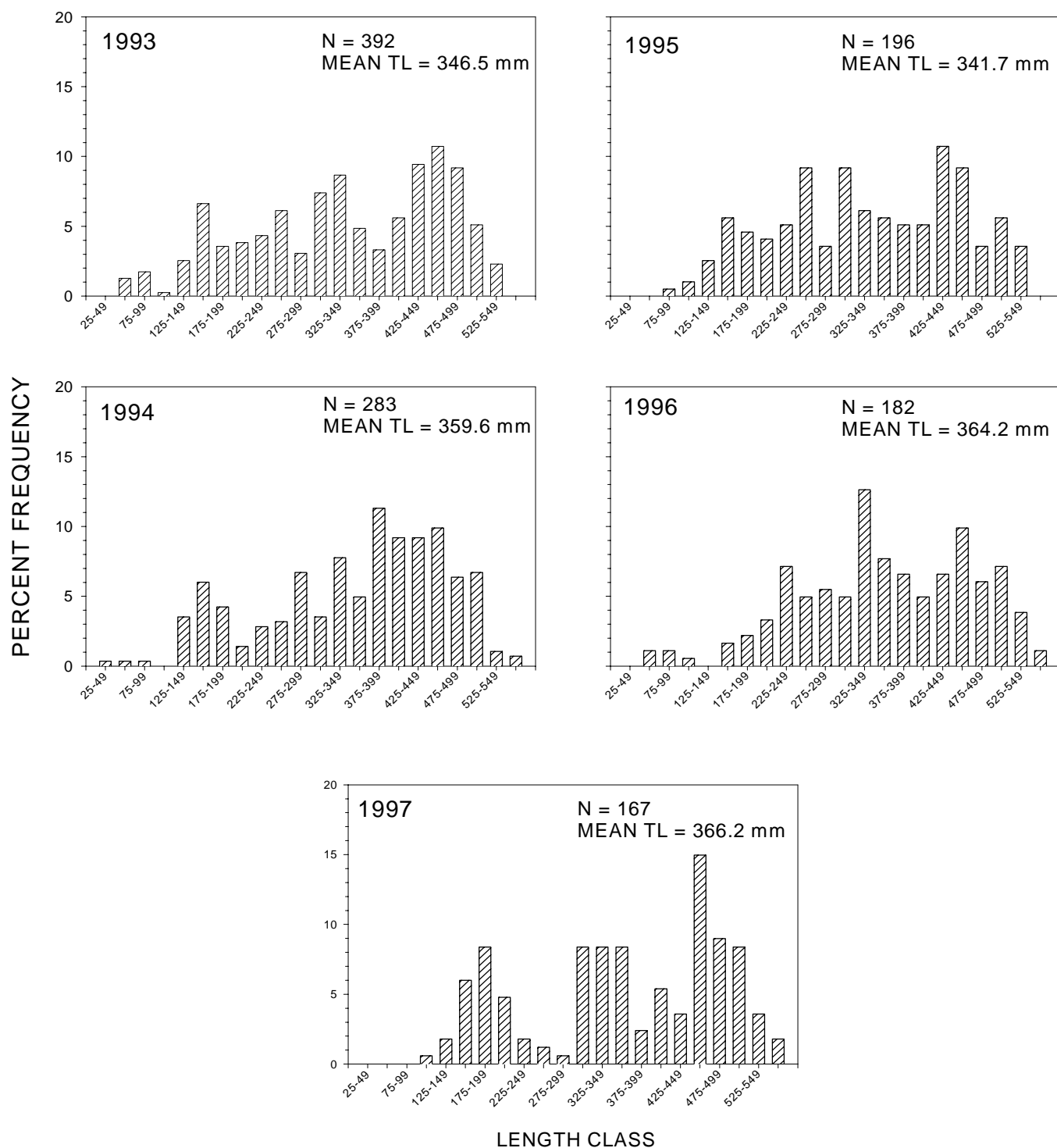
Figure 7. Size-structure of the flannelmouth sucker, *Catostomus latipinnis*, population in Geomorphich Reach 5, San Juan River, 1993 - 1997.
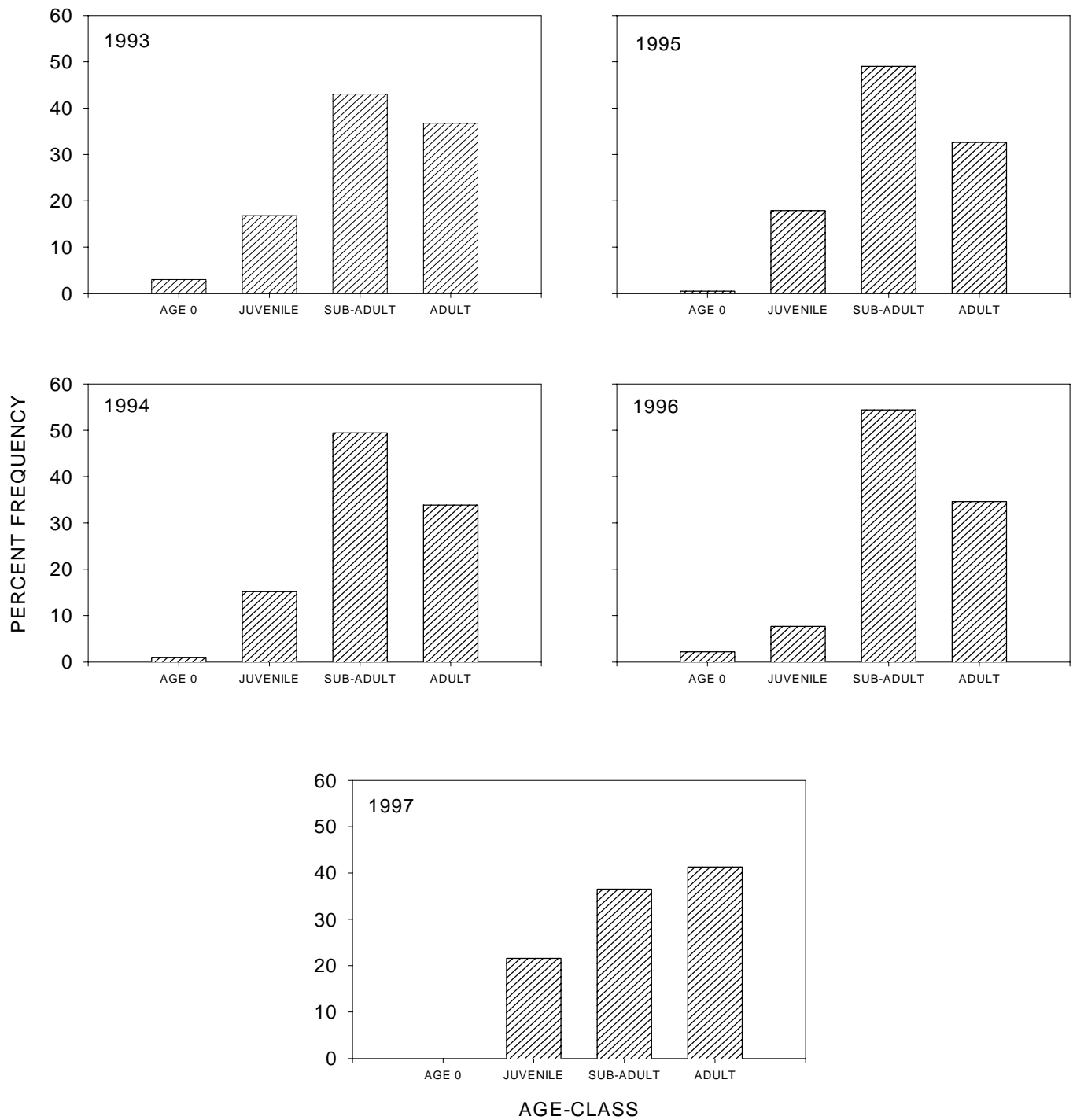
Figure 8. Age-structure of the flannelmouth sucker, *Catostomus latipinnis*, population in Geomorphic Reach 5, San Juan River, 1993 - 1997.
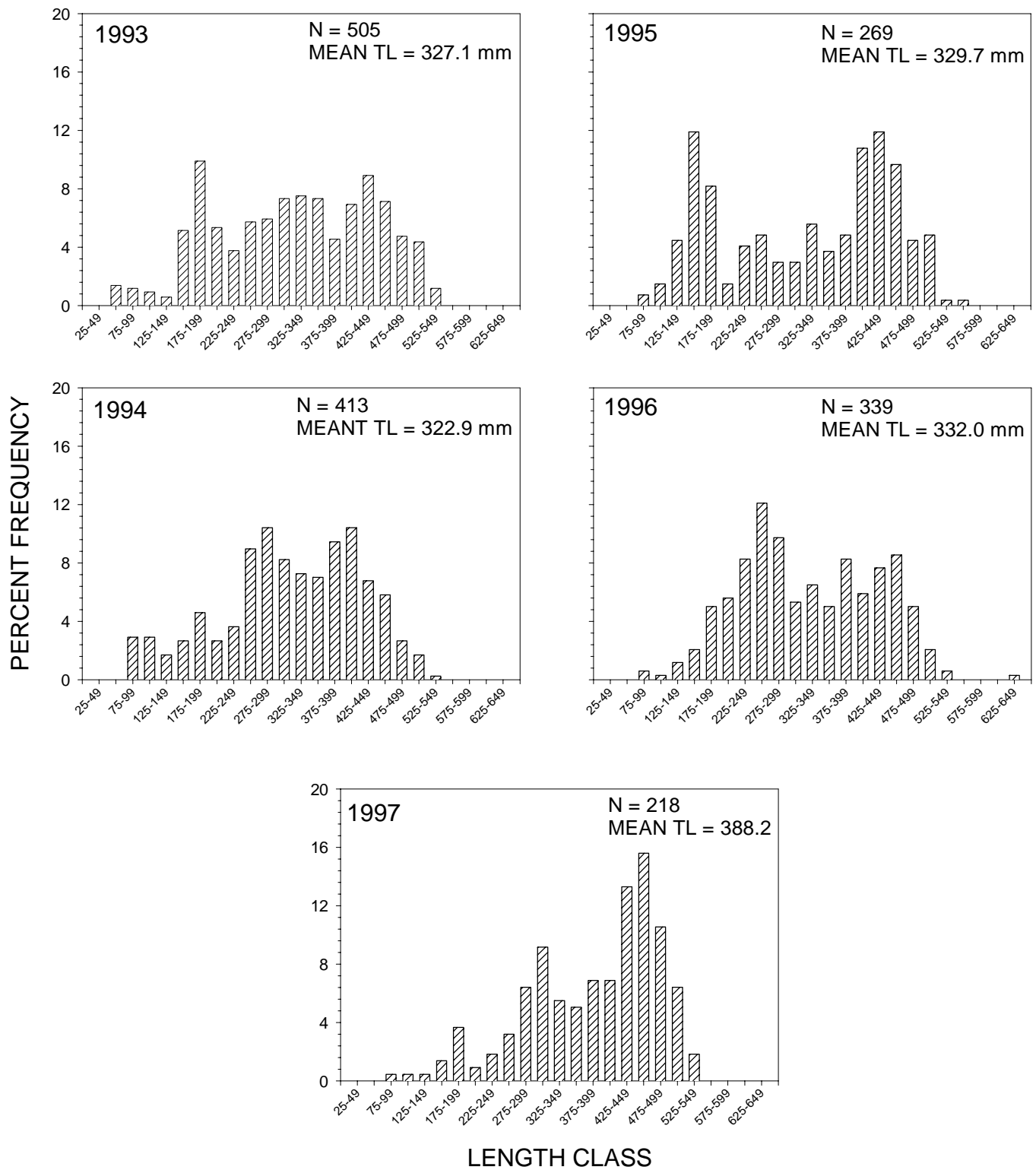
Figure 9. Size-structure of the flannelmouth sucker, *Catostomus latipinnis*, population in Geomorphic Reach 4, San Juan River, 1993 - 1997.

24
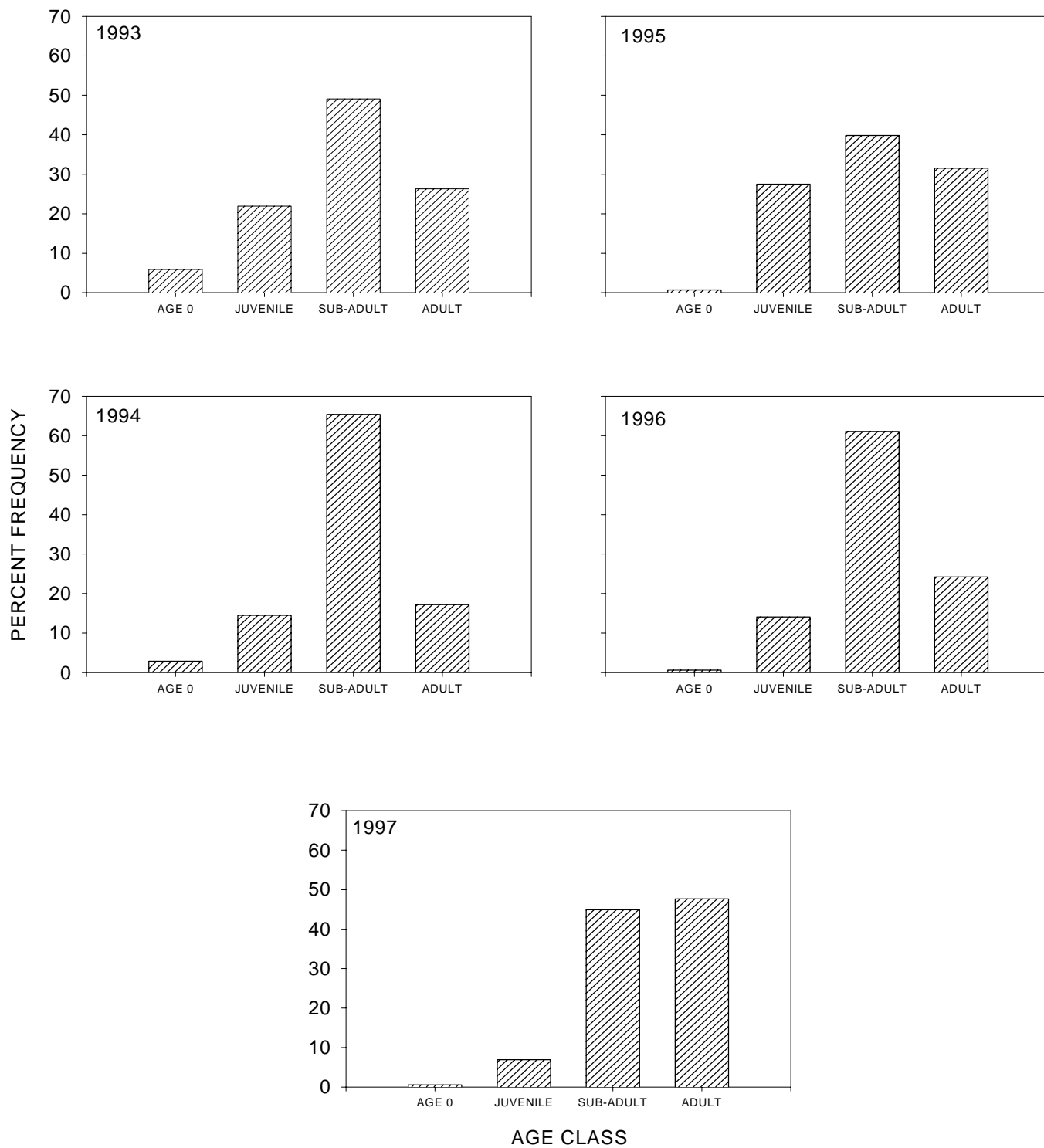
Figure 10. Age-structure of the flannelmouth sucker, *Catostomus latipinnis*, population in Geomorphic Reach 4, San Juan River, 1993 - 1997.
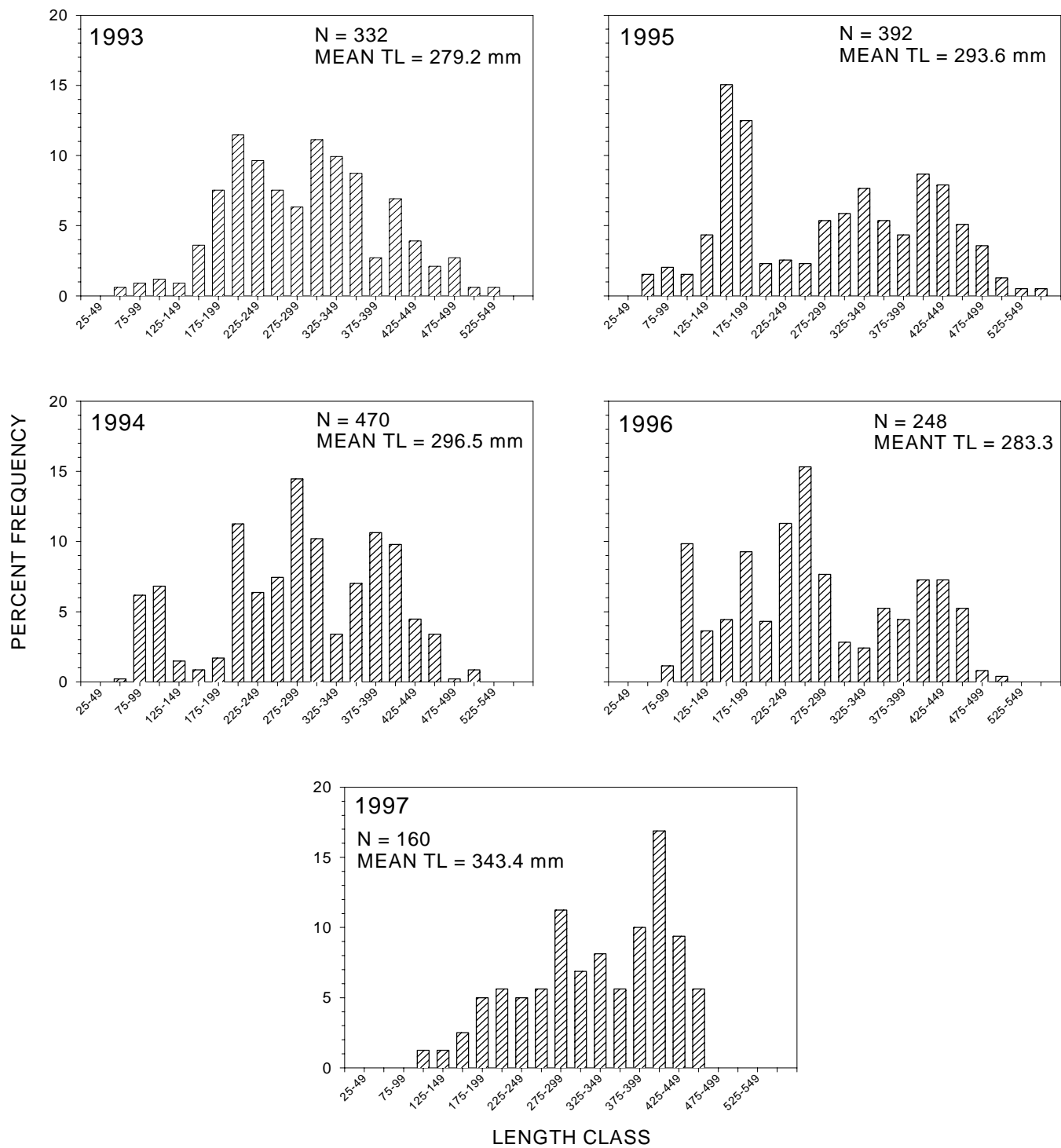
Figure 11. Size-structure of the flannelmouth sucker, *Catostomus latipinnis*, population in Geomorphic Reach 3, San Juan River, 1993 - 1997.

were not significant (Table 7). Throughout the 5-year period, sub-adults were the most abundant age-class, by a large margin in most years, in Reach 3 collections (Figure 13). Abundance of flannelmouth sucker in Reach 3 declined from 1993 through 1997, but mean TL did not change substantially from year-to-year until 1997 when it increased markedly (Figure 9).

Among reaches and across years, significant differences in mean abundance of flannelmouth sucker were noted. Two-way ANOVA yielded F = 5.67 (p = 0.029) for reach comparisons and F = 7.906 (p = 0.007) for year comparisons. Among reach comparisons of annual mean TL yielded significant differences (F = 22.73, p = 0.015).

Total biomass of flannelmouth sucker was higher in Reaches 5 and 4 in 1993 and 1994 than in subsequent years (Figure 14). In Reach 3, total biomass was greatest in 1994 and 1995. Between Reaches 5 and 4 differences in total biomass were slight. Total biomass in Reach 3 was substantially less, each year, than in upstream reaches. These differences, however, were not significant (F = 2.02, p = 0.153). Mean biomass in Reaches 5 and 4 varied considerably among years, but remained fairly constant in Reach 3. Differences in mean biomass were significant (F = 6.65, p = 0.011) and post hoc tests indicated that mean biomass in Reach 3 was statistically less than in Reach 5 (p = 0.011).

Bluehead sucker – Changes in the size-structure of the bluehead sucker population in Geomorphic Reach 5 during the study was, in part, a function of differences in sample size. For example, in 1993 and 1997 moderate numbers (> 60) were collected and a variety of size-classes were present, with most individuals between 300 and 375 mm TL (Figure 15). But in 1995 only 9 specimens were collected and all were ≥ 250 mm. In 1994 and 1996 intermediate numbers of bluehead sucker were collected, but a variety of sizes were present. Observed size-structure differences, however, were not significant (Table 8). Four age-classes were present in 1993, 1994 and 1996; only subadults were collected in 1995 and juveniles and subadults in 1997 (Figure 16). Abundance of bluehead sucker in Reach 5 declined considerably from 1993 to 1995 and then increased through 1997 (Figure 17). Mean total length varied among years but was near 300 mm.

Bluehead suckers ranged in size from <100 to >400 mm in all years, except 1997, in Geomorphic Reach 4; in 1997 the size range was more restricted and most individuals were 275 to 349 mm (Figure 18). Differences were not significant (Table 8). Four age-classes were collected in 1993 and 1994 and three in subsequent years (Figure 19). Age-0 specimens were collected only in 1993 and 1994 and subadults numerically dominated collections each year except 1994. Abundance of bluehead sucker in Reach 4 was similar to that in Reach 5, with abundance greatest in 1993, declining through 1995, and increasing through 1997 (Figure 17). In each year, except 1995, abundance was less in Reach 4 than Reach 5. Mean TL was about 275 mm in all years except 1994 when it was about 240 mm.

Few bluehead suckers were collected in Geomorphic Reach 3 in any year, and the species was not found there in 1995. Specimens <150 mm were not collected and most were between 250 and 375 mm in all years (Figure 20). Differences in size-structure were not significant for the years compared (Table 8). No Age-0 and few juvenile specimens were captured in this reach; most (> 60%) were sub-
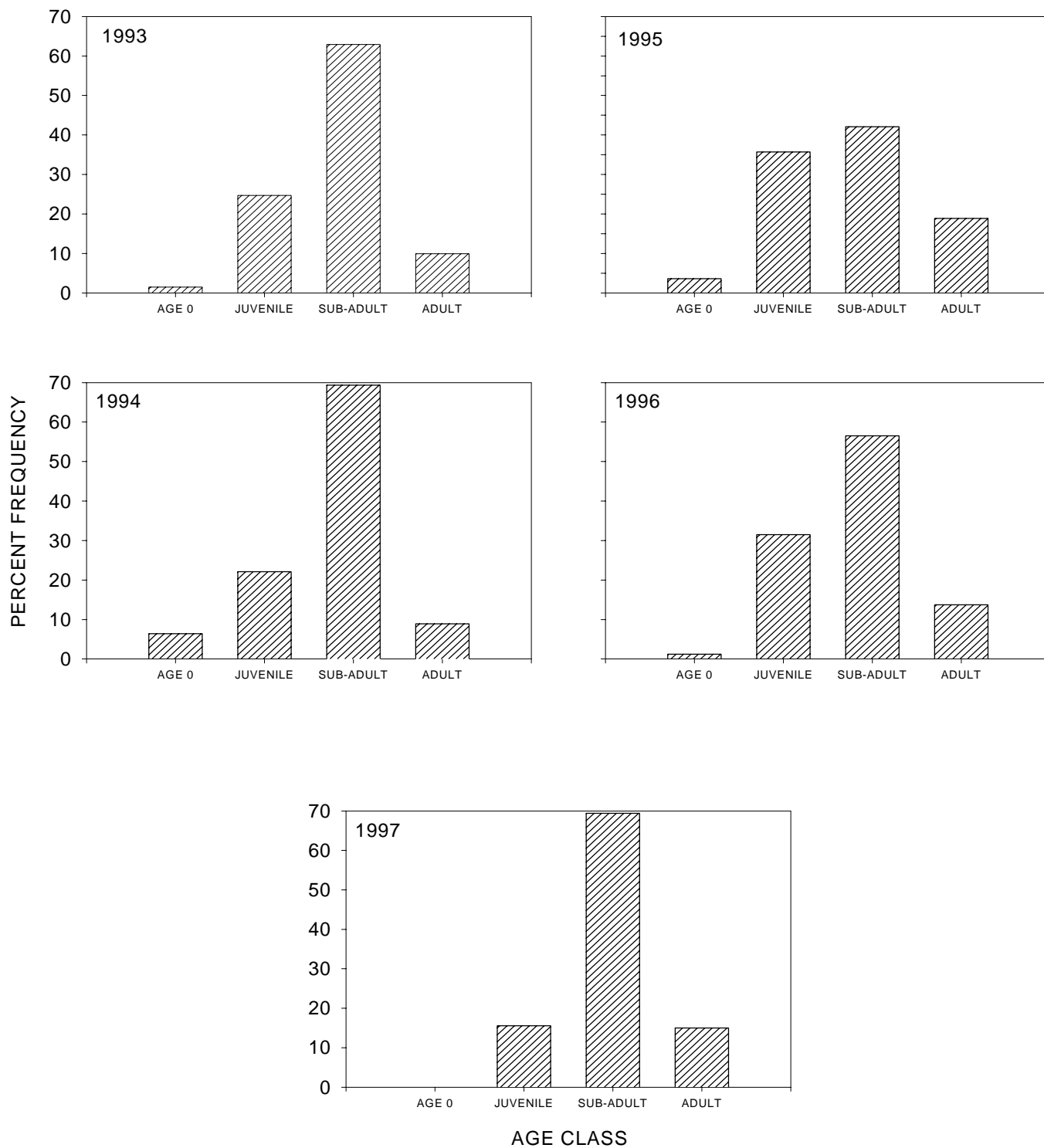
Figure 12. Age-structure of the flannelmouth sucker, *Catostomus latipinnis*, population in Geomorphic Reach 3, San Juan River, 1993 - 1997.

Figure 13. Biomass of flannelmouth sucker, *Catostomus latipinnis*, in San Juan
River secondary channels during spring inventories, 1993 - 1997.
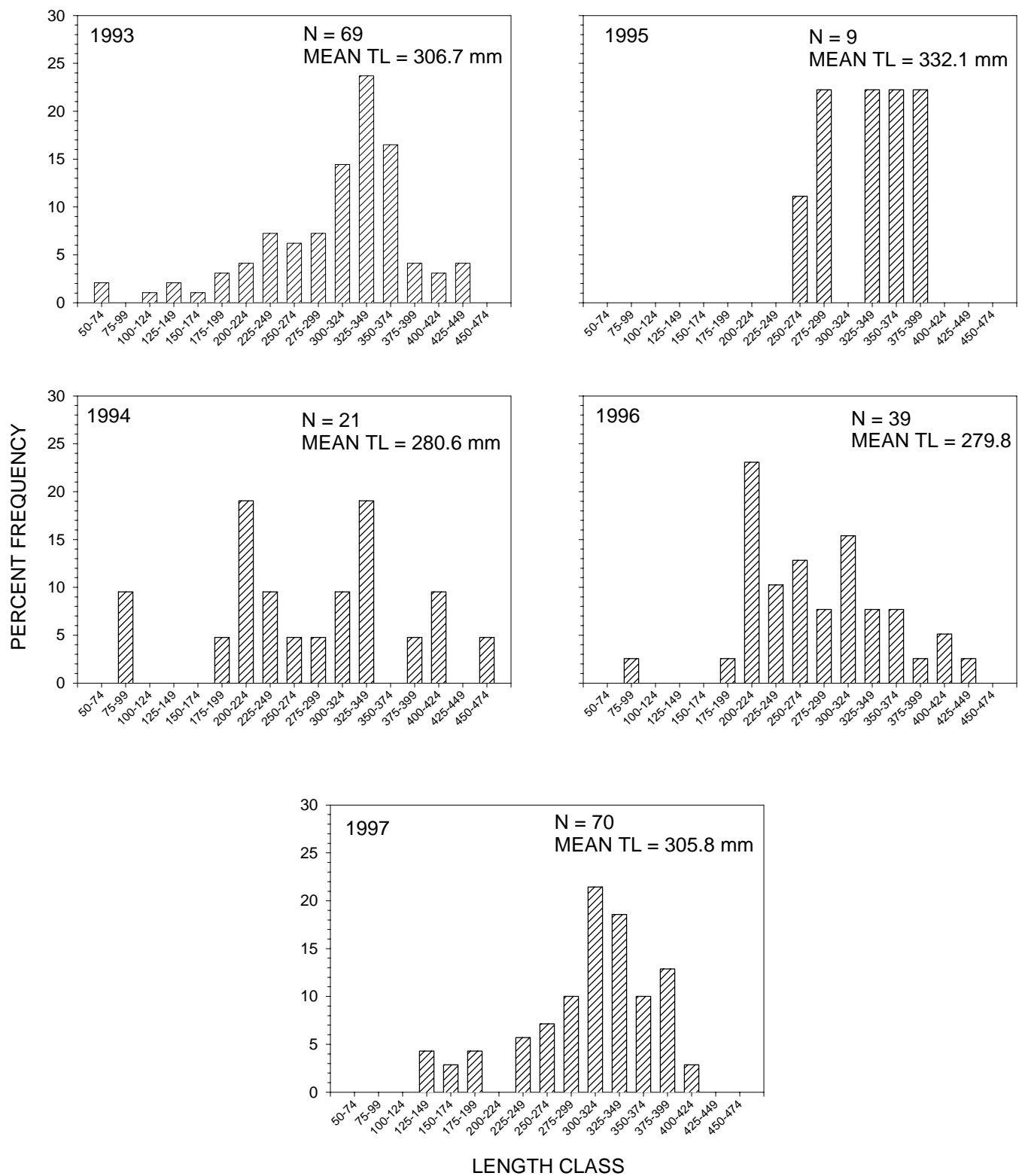
Figure 14. Size-structure of the bluehead sucker, *Catostomus discobolus*,
population in Geomorphic Reach 5, San Juan River, 1993 - 1997.
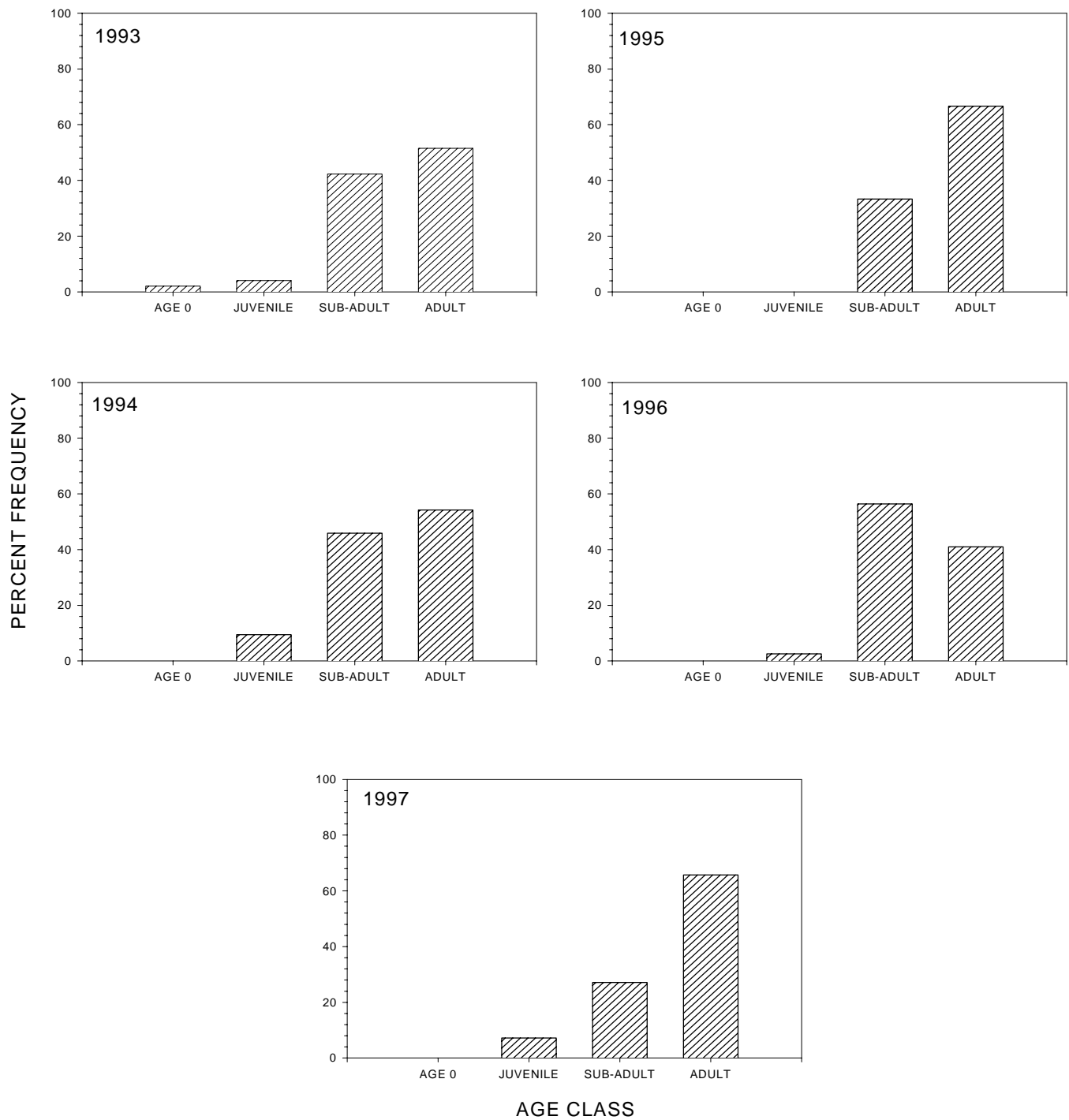
Figure 15. Age-structure of the bluehead sucker, *Catostomus discobolus*, population in Geomorphic Reach 5, San Juan River, 1993 - 1997.
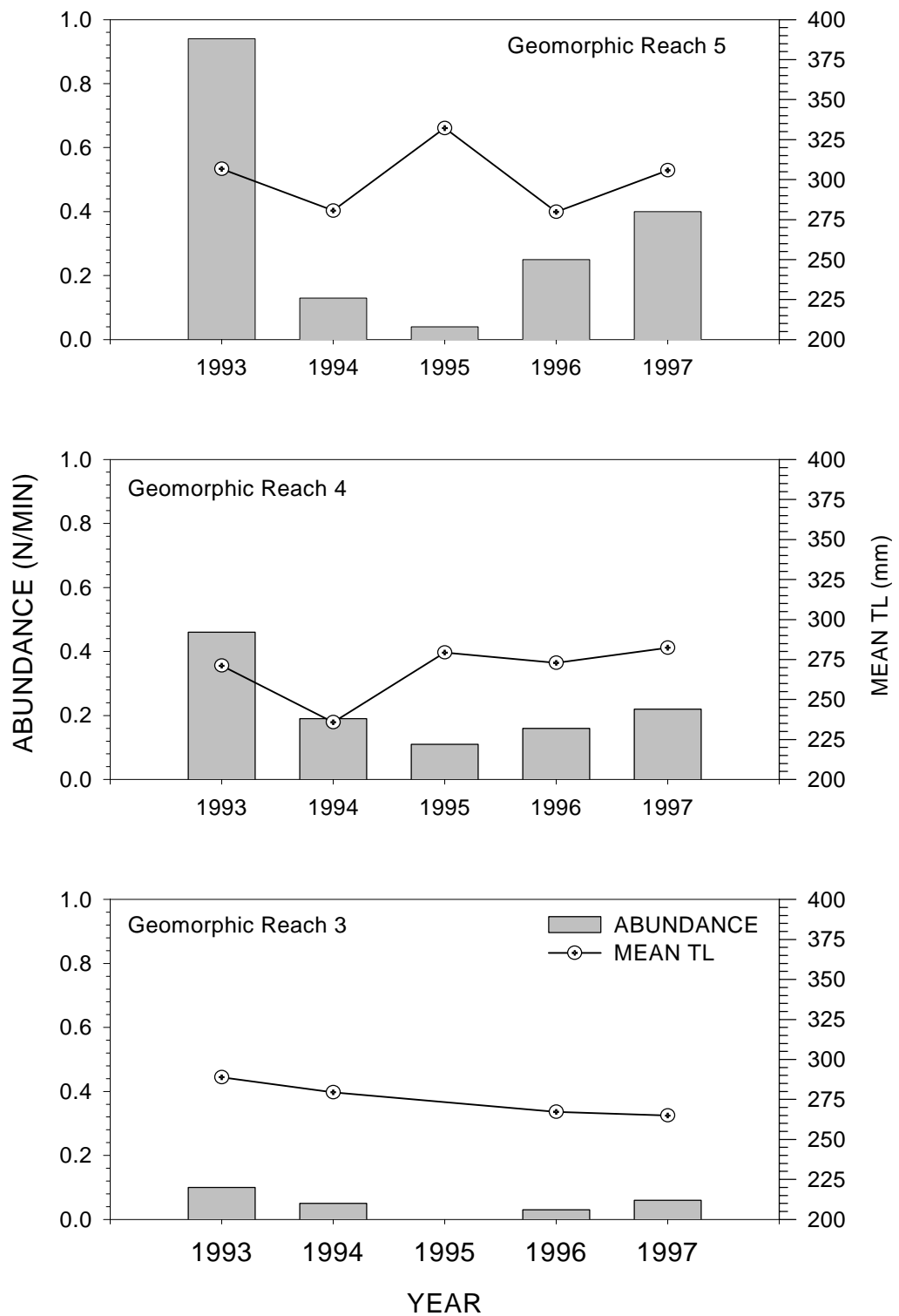
Figure 16. Abundance and mean total length of bluehead sucker, *Catostomus discobolus*, in San Juan River secondary channels during spring, 1993 - 1997.
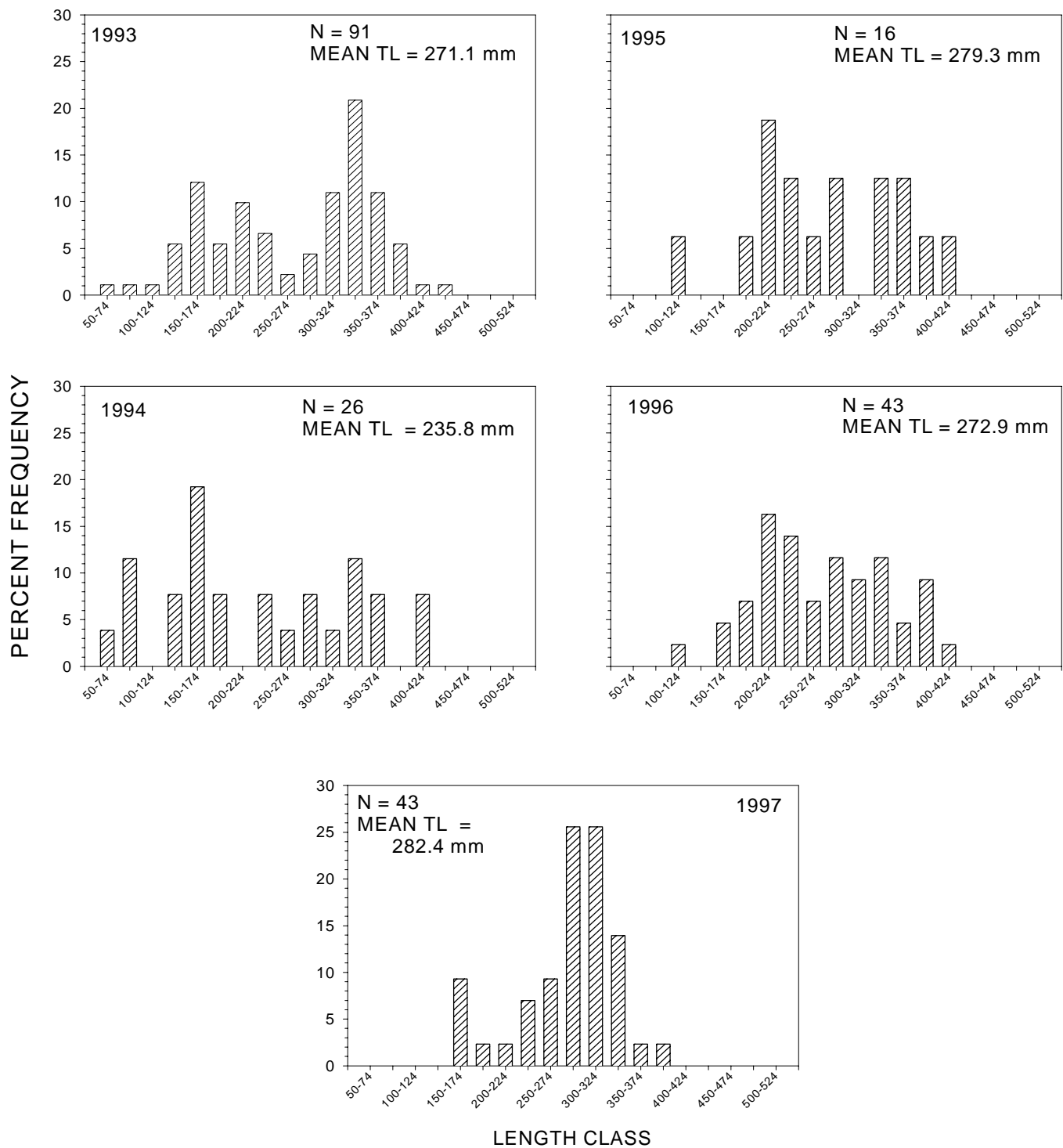
Figure 17. Size-structure of the bluehead sucker, *Catostomus discobolus*, population in Geomorphic Reach 4, San Juan River, 1993 - 1997.
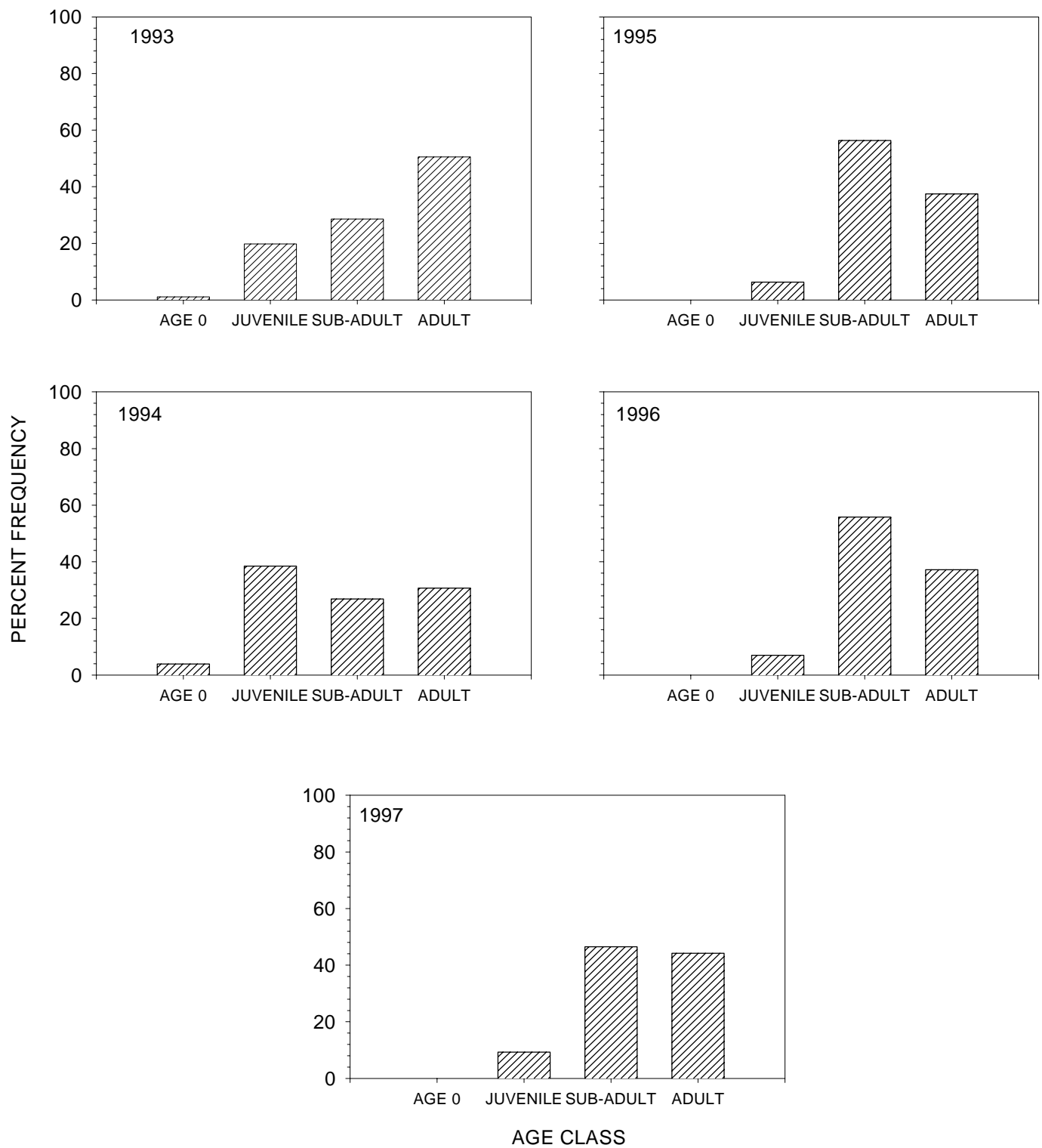
Figure 18. Age-structure of the bluehead sucker, *Catostomus discobolus*, population in Geomorphic Reach 4, San Juan River, 1993 - 1997.
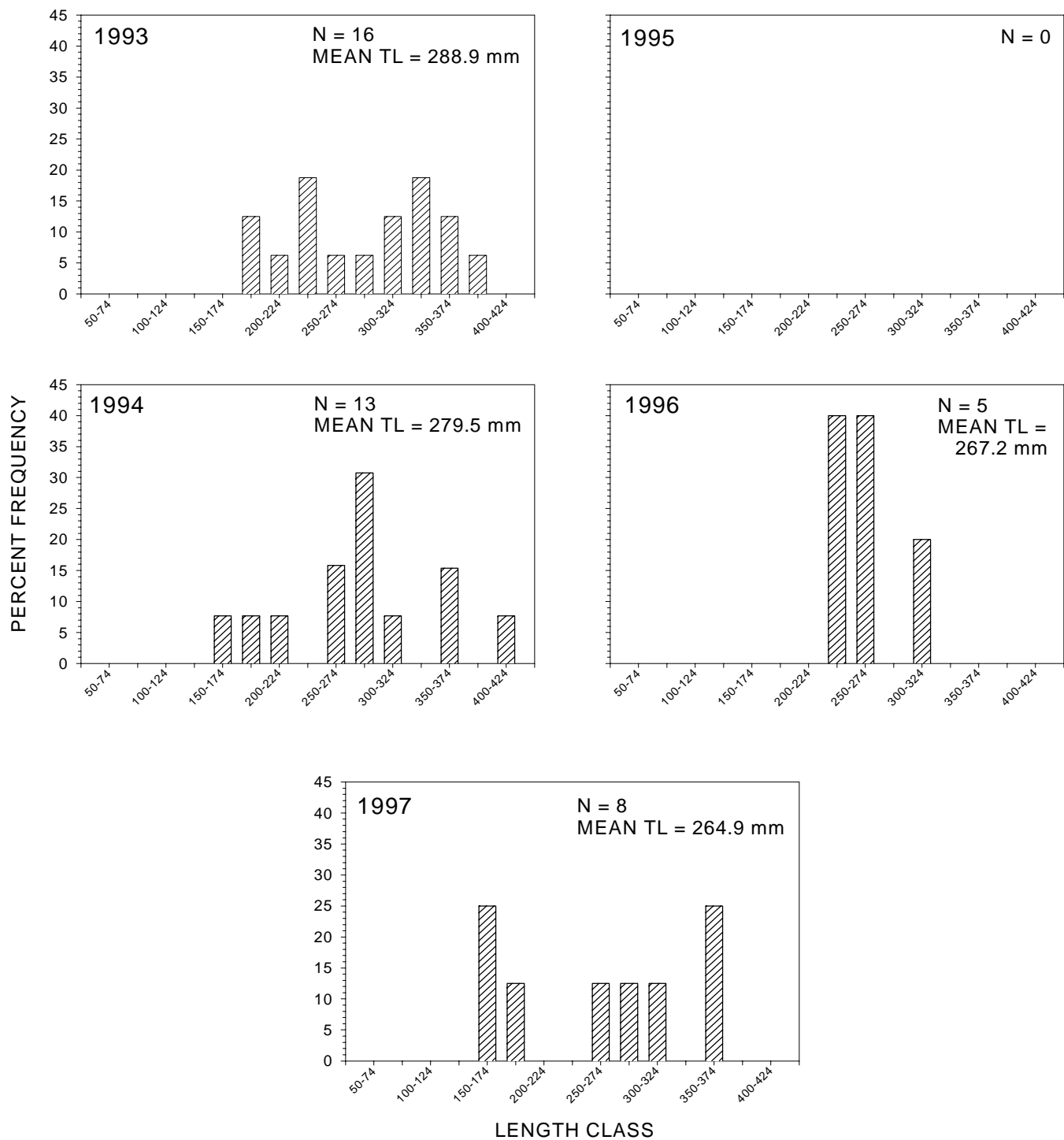
Figure 19. Size-structure of the bluehead sucker, *Catostomus discobolus*, population in Geomorphic Reach 3, San Juan River, 1993 - 1997.

Table 8. Results of Kolomogorov-Smirov (D_{max}) sequential comparisons of size-structure of bluehead suckers in San Juan River secondary channel collections, spring 1993 – 1997.

	YEARS	D_{MAX}	SIGNIFICANCE
GEOMORPHIC REACH 5	93 – 94	-0.2273	NS
	94 – 95	0.2727	NS
	95 – 96	-0.2527	NS
	96 – 97	-0.1800	NS
GEOMORPHIC REACH 4	93 – 94	0.1818	NS
	94 – 95	0.1818	NS
	95 – 96	0.1473	NS
	96 - 97	0.1273	NS
GEOMORPHIC REACH 3	93 – 94	-0.1364	NS
	94 – 95[1]	--	--
	95 – 96[1]	--	--
	96 – 97	-0.1527	NS

[1]No bluehead sucker was collected in Geomorphic Reach 3 in 1995; therefore K-S D_{max} was not calculated for 94 – 95 and 95 – 96 comparisons.

adults or adults (Figure 21). The decline in abundance from 1993 through 1995 and increase to 1997 was like that noted in Reaches 5 and 4 (Figure 17). Unlike Reaches 5 and 4, however, mean TL decreased from 1993 through 1997 in Reach 3.

There were no significant differences in bluehead sucker abundance among years (F = 4.25, p = 0.055) or among reaches (F = 3.31, p = 0.070). Differences in mean TL among reaches were significant (F = 4.93, p = 0.040).

Total biomass of bluehead sucker was least in all reaches in 1995 and greatest in 1993 (Figure 22). Between 1993 and 1997, mean biomass increased in Reach 5, but was not substantially different in Reaches 4 and 3. In most years, total biomass was greater in Reach 5 than downstream reaches. Mean biomass in Reach 5 was > 300 g in all years except 1993, in Reach 4 mean biomass exceeded 300 g only in 1996, and never exceeded 300 g in Reach 3. Among reach comparisons did not yield significant differences for either total or mean biomass (F = 3.51, p = 0.063 and F = 1.91, p = 0.191).

Common carp—Reach 5 secondary channel collections yielded only adult common carp in all years, except 1994, and almost all individuals were > 400 mm TL (Figure 23). Sequential annual comparisons did not yield significant differences (Table 9). From 1993 through 1995, there was a slight decline in common carp abundance, but it increased in 1996 and 1997 (Figure 24). Abundance in 1997 was almost twice that of 1993, 1994, and 1995. Mean length varied little among the years.

Individuals >400 mm TL numerically dominated collections of common carp in Reach 4 (Figure 25). In contrast to Reach 5, a few individuals <250 mm (juveniles and sub-adults) were collected in Reach 4. There were no differences in size-structure of common carp in Reach 4 (Table 9). Abundance, and absolute numbers declined from 1993 through 1995, but increased in 1996 and 1997 (Figure 24).
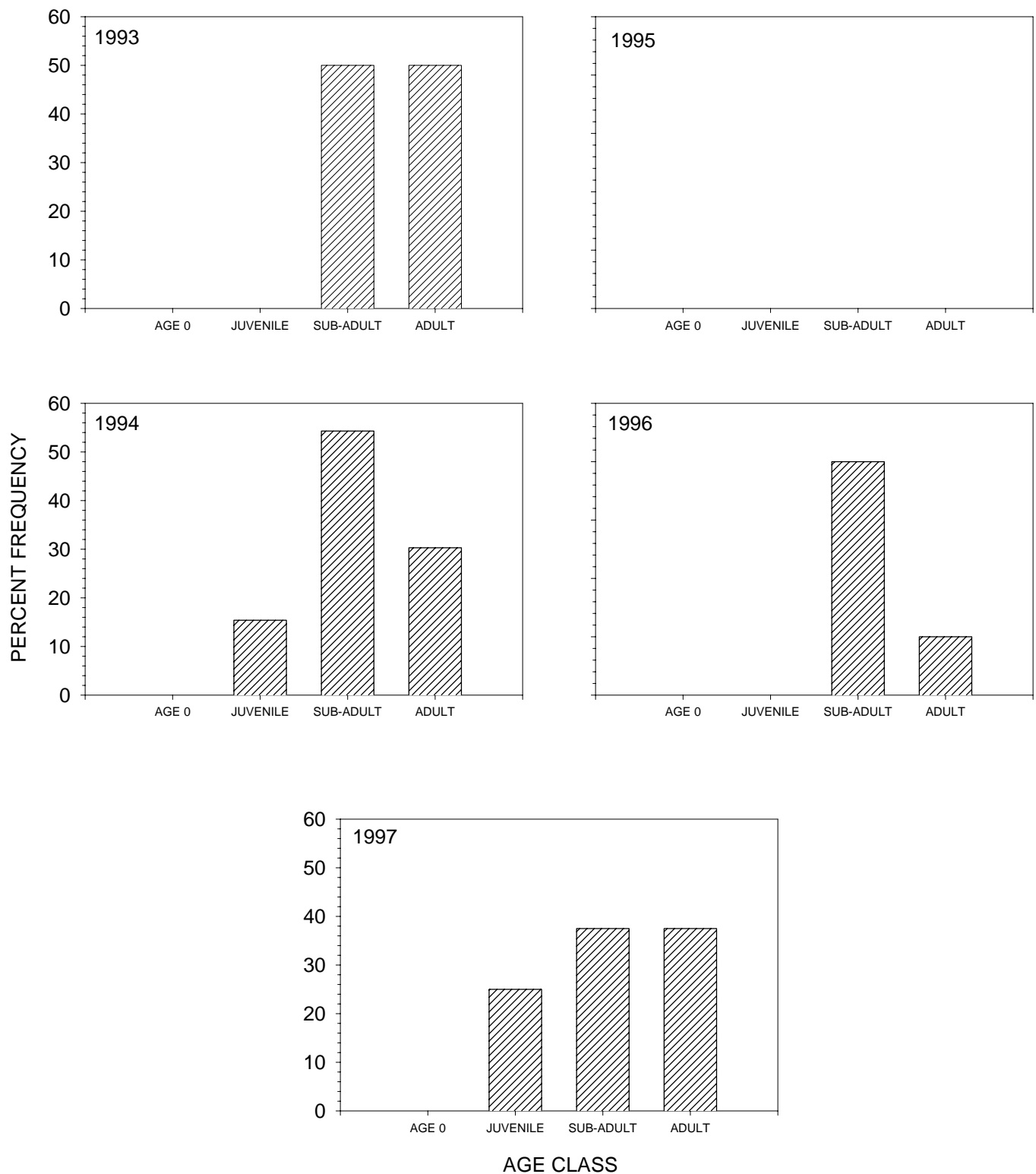
Figure 20. Age-structure of the bluehead sucker, *Catostomus discobolus*,
population in Geomorphic Reach 3, San Juan River, 1993 - 1997.
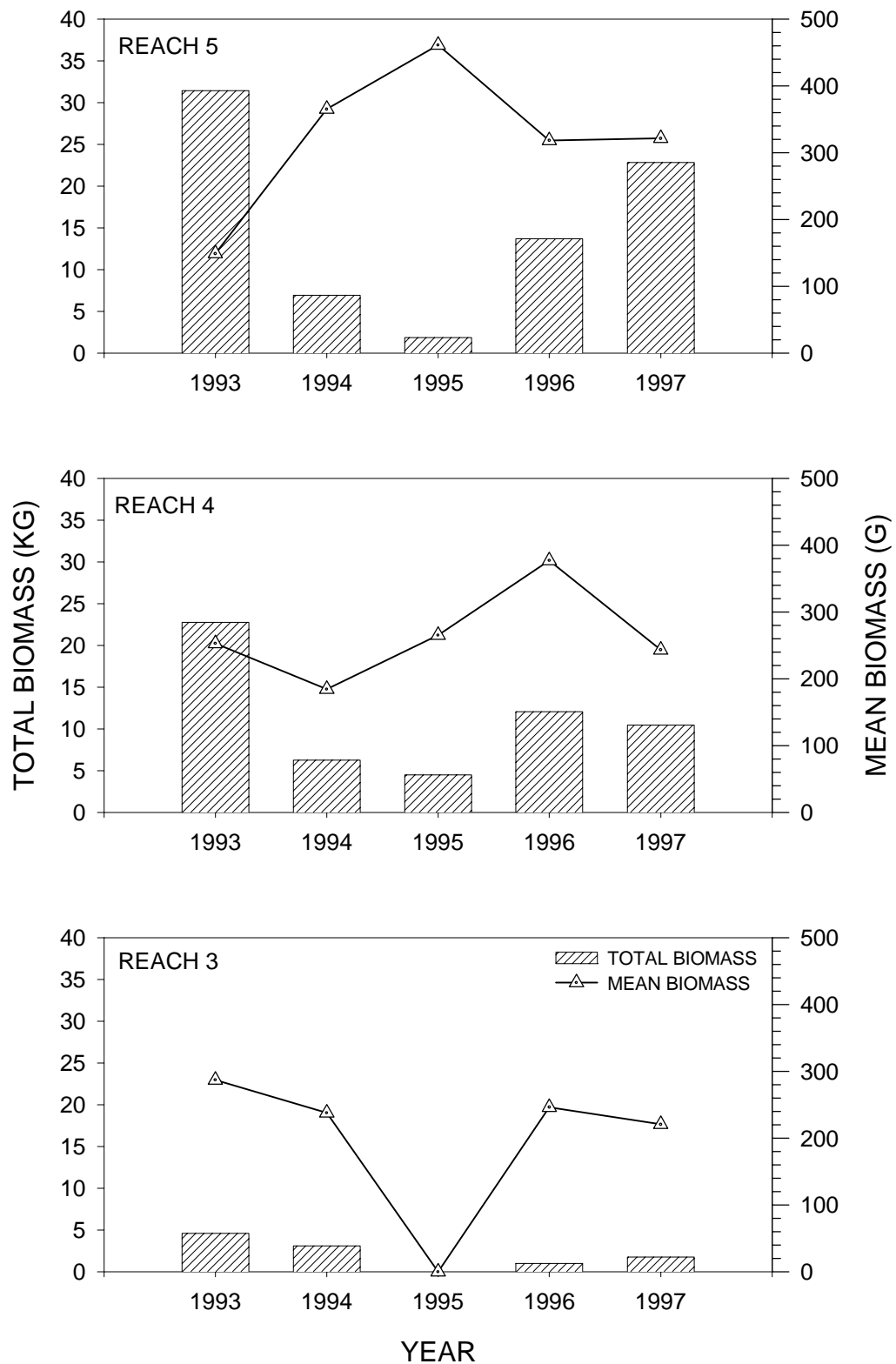
Figure 21. Total and mean biomass of bluehead sucker, *Catostomus discobolus*,
in San Juan River secondary channels during spring inventories,
1993 - 1997.

Figure 22. Size-structure of the common carp, *Cyprinus carpio,* population
in Geomorphic Reach 5, San Juan River, 1993 - 1997.
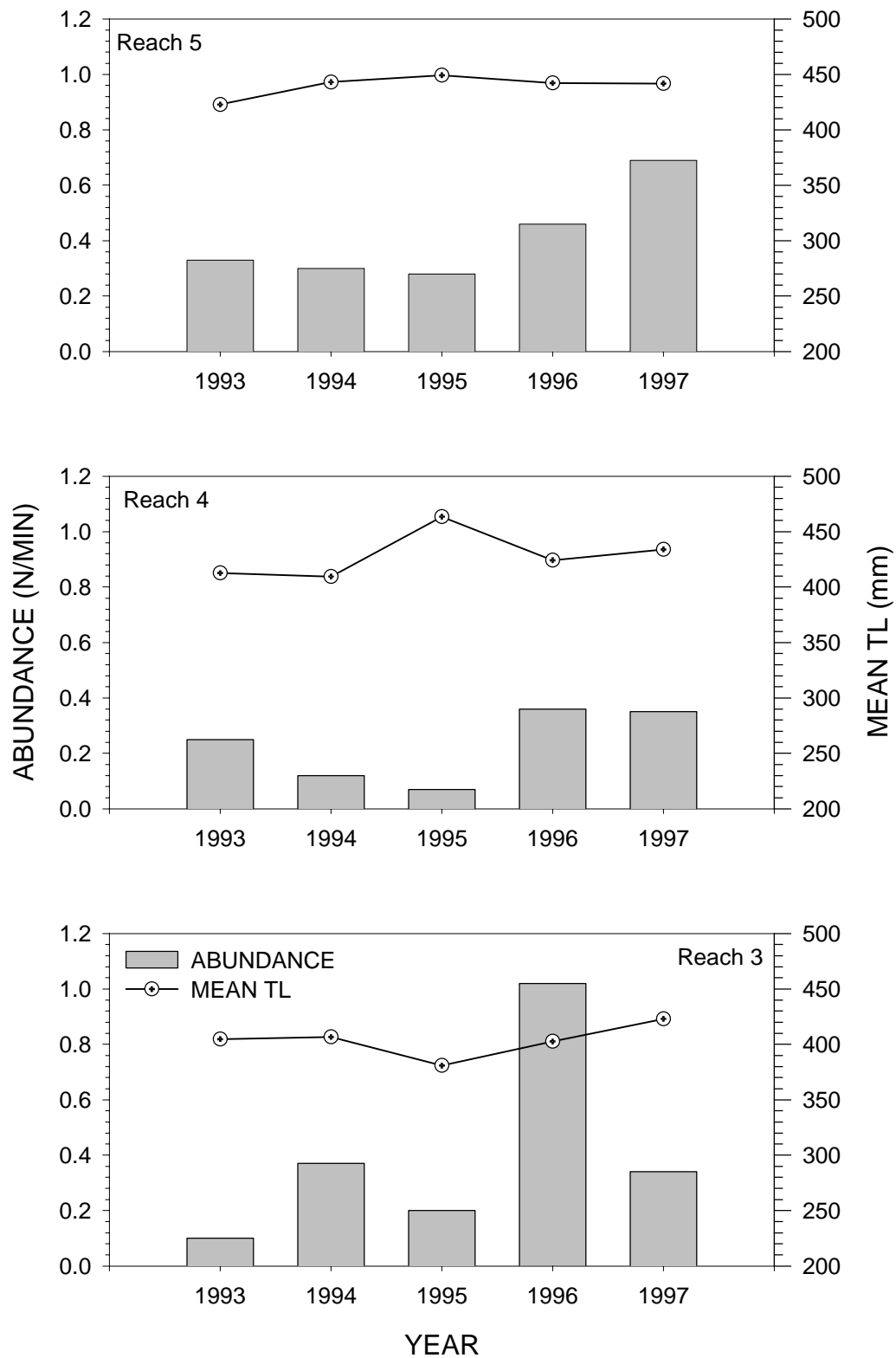
Figure 23. Abundance and mean total length of common carp, *Cyprinus carpio*, in San Juan River secondary channels during spring, 1993 - 1997.
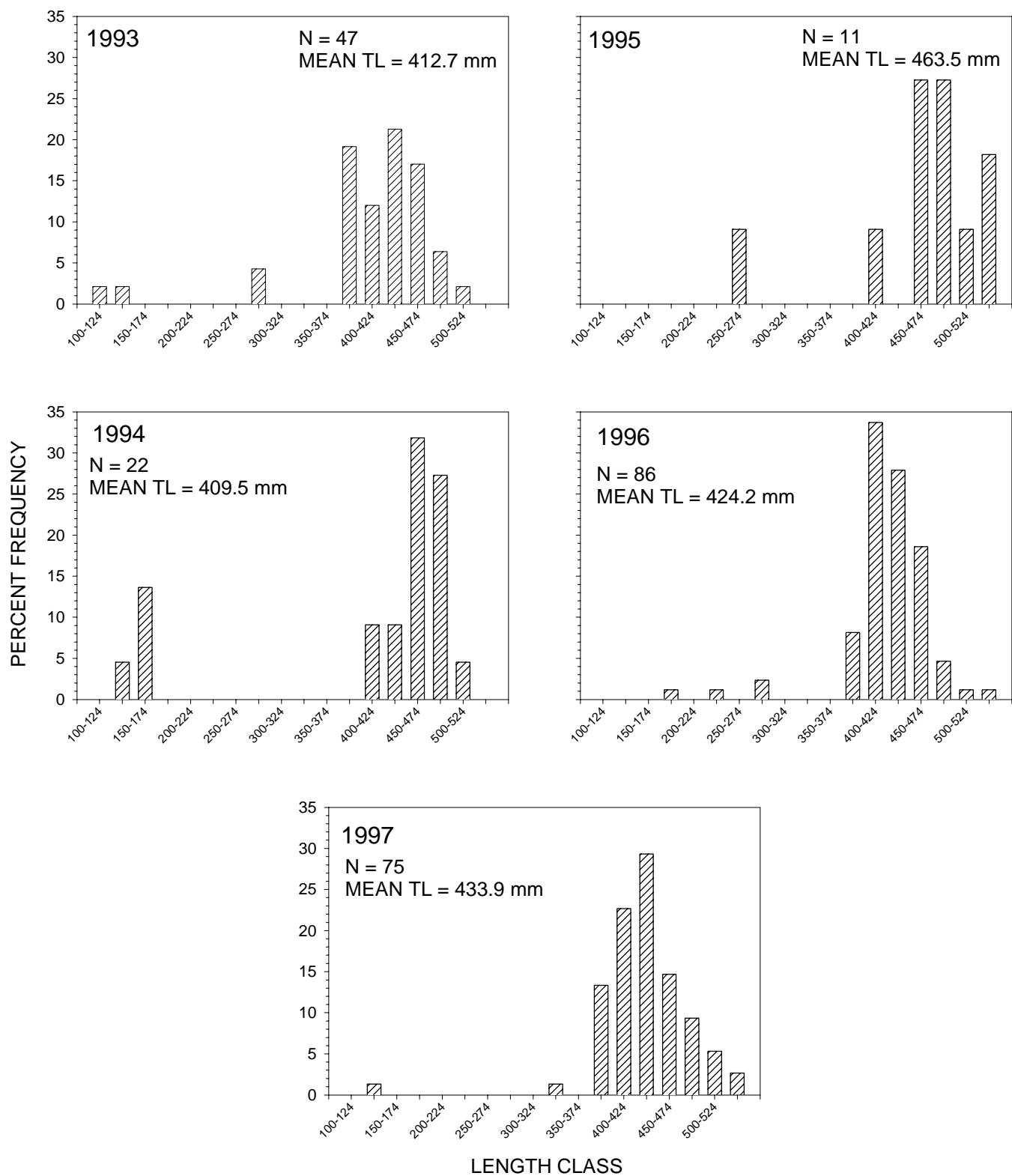
Figure 24. Size-structure of the common carp, *Cyprinus carpio*, population in Geomorphic Reach 4, San Juan River, 1993 - 1997.

The Reach 4 decline in abundance was greater than in Reach 5 and the 1996 and 1997 Reach 4 increase was less. Except for 1995, mean TL was between 410 and 434 mm.

Table 9. Results of Kolomogorov-Smirnov (D_{max}) sequential comparisons of size-structure of common carp in San Juan River secondary channel collections, spring 1993 – 1997.

	YEARS	D_{MAX}	SIGNIFICANCE
GEOMORPHIC REACH 5	93 – 94	-0.1364	NS
	94 – 95	0.1364	NS
	95 – 96	-0.1127	NS
	96 – 97	-0.0781	NS
GEOMORPHIC REACH 4	93 – 94	-0.1364	NS
	94 – 95	-0.0909	NS
	95 – 96	0.1527	NS
	96 – 97	0.1691	NS
GEOMORPHIC REACH 3	93 – 94	-0.3636	NS
	94 – 95	0.2727	NS
	95 – 96	0.3564	NS
	96 – 97	-0.2418	NS

Although most individuals collected were >400 mm TL, a larger proportion of common carp specimens were <250 mm, in several years, in Reach 3 than either upstream Reach (Figure 26). Annual differences in the size-structure of the common carp population in Reach 3 were not significant (Table 9). Abundance and absolute numbers of common carp collected varied considerably among years in Reach 3 (Figure 24). In 1996, abundance exceeded 1.0 fish/minute, but in 1993 it was <0.1 fish/minute. Mean TL was about 400 mm and changed little among years.

No among-year or among reach abundance differences were noted for common carp (F = 2.57, p = 0.120; F = 1.39, p = 0.304). Among-reach differences in mean TL were significant (F = 5.76, p = 0.028).

In each reach, total biomass of common carp varied among years (Figure 27). In Reaches 5 and 4, it was least in 1995 and least in Reach 3 in 1993. Common carp biomass was greatest in 1996 or 1997 in all reaches. Mean biomass varied less than total biomass; in average, Reach 4 had the largest common carp and Reach 3 the smallest. In Reaches 4 and 3, mean biomass was greater in 1997 than 1993. Neither total nor mean biomass of common carp was significantly different among Reaches (F = 0.417, p = 0.668 and F = 3.198, p = 0.077).

Channel catfish—Between 1993 and 1995, most channel catfish collected in Reach 5 were between 400 and 575 mm TL, but in 1996 and 1997 a substantial proportion of the samples were 250 to 375 mm (Figure 28). Size-structure differences were not significantly different (Table 10). From 1993 through 1996, channel catfish abundance in Reach 5 was <0.2 fish/min, but in 1997 abundance was near 0.4 fish/min (Figure 29). Mean TL generally declined from 1993 through 1996 and increased, slightly, in 1997. In 1993, almost all channel catfish captured in Reach 5 were adults (>301 mm TL),
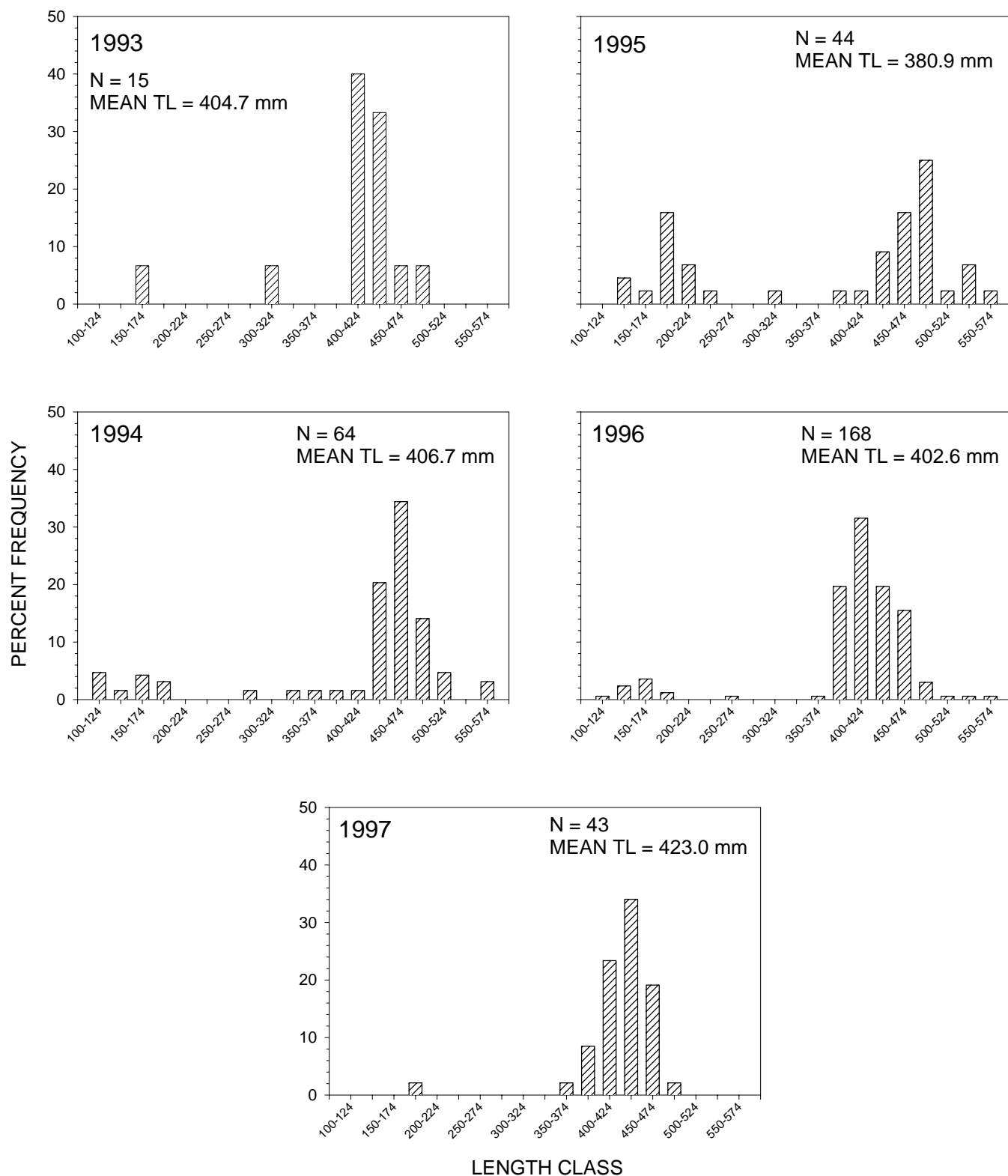
Figure 25. Size-structure of the common carp, *Cyprinus carpio*, population in Geomorphic Reach 3, San Juan River, 1993 - 1997.
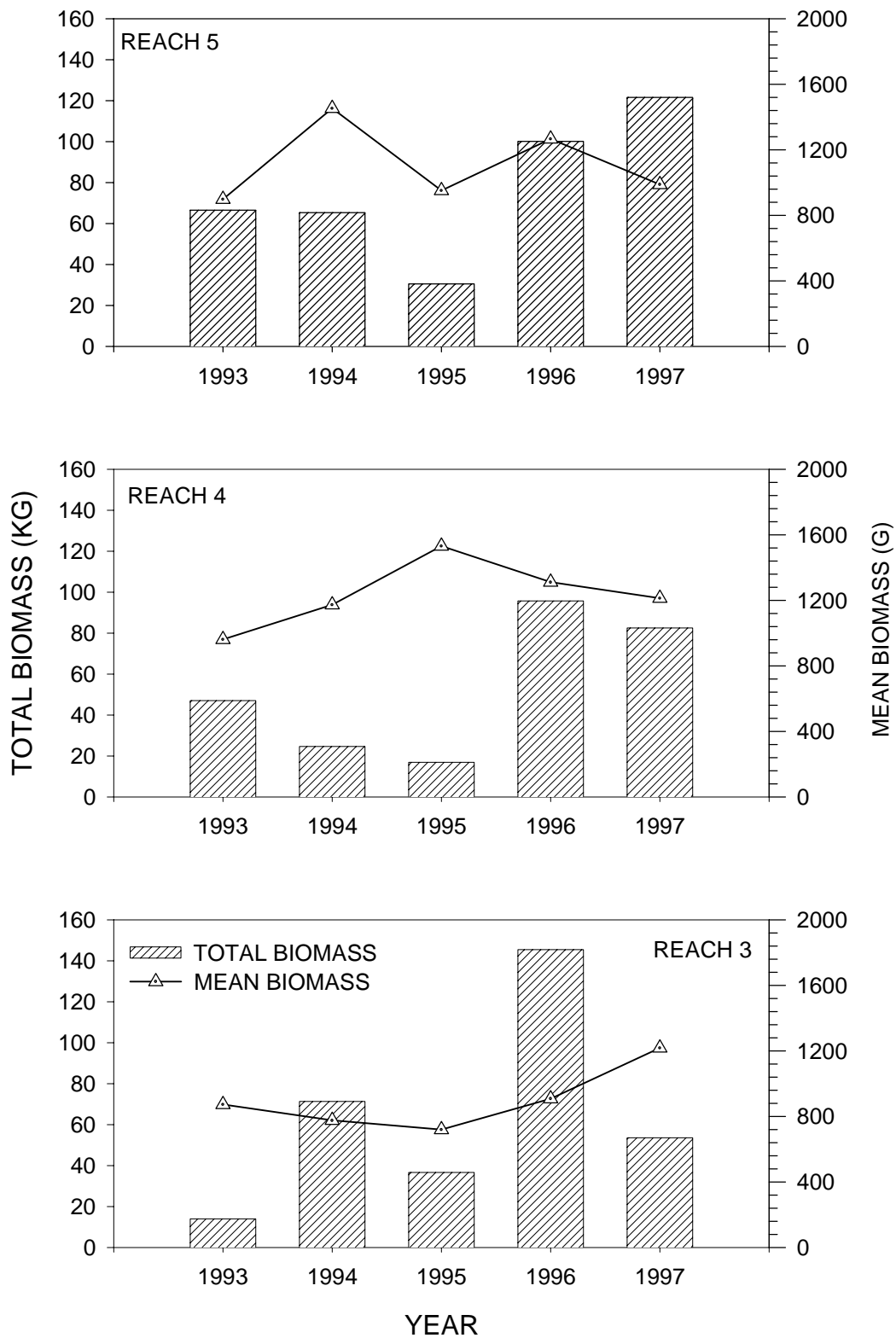
Figure 26. Total and mean biomass of common carp, *Cyprinus carpio*, in San
Juan River secondary channels during spring inventories, 1993 - 1997.
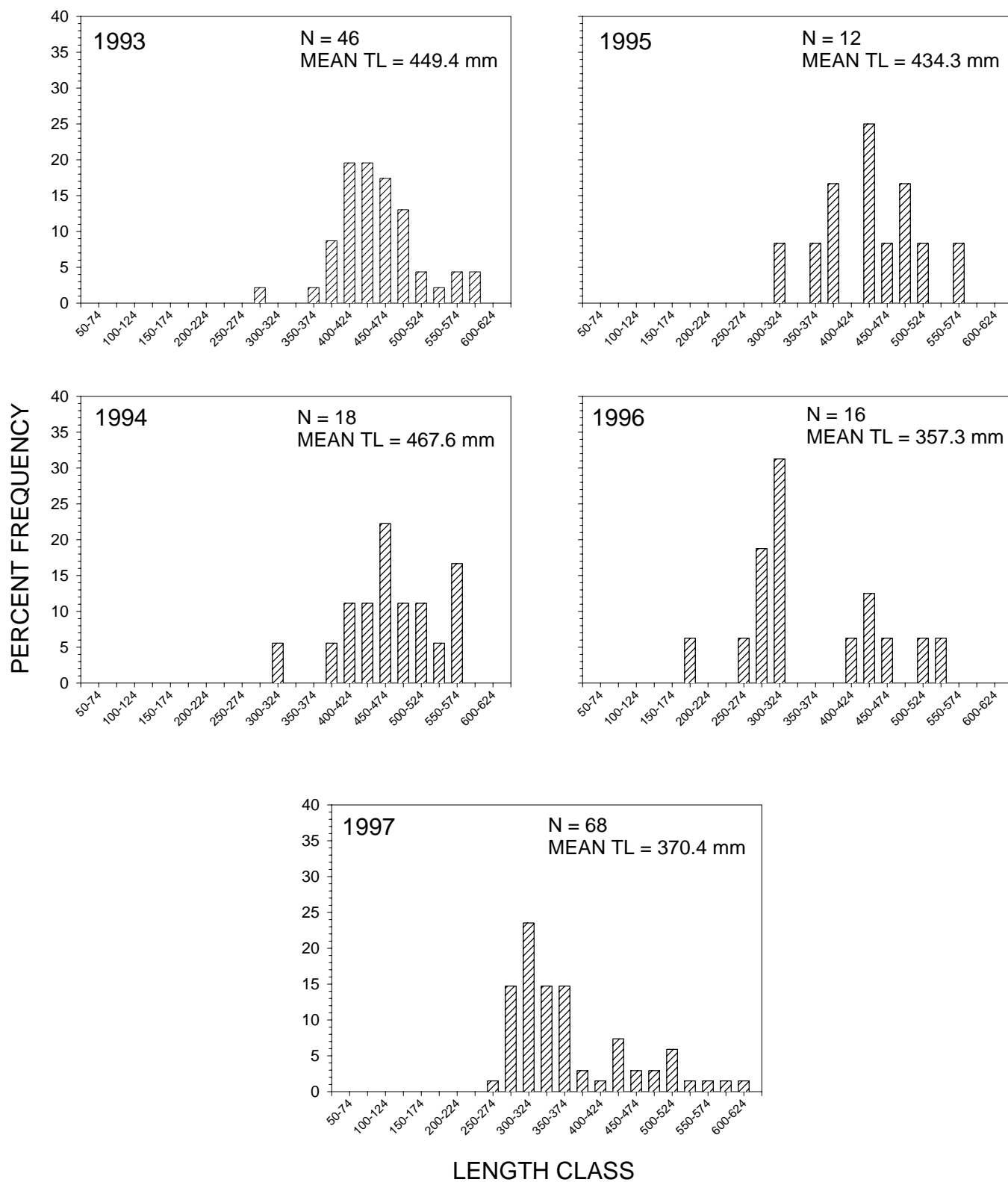
Figure 27. Size-structure of the channel catfish, *Ictalurus punctatus*,
population in Geomorphic Reach 5, San Juan River, 1993 - 1997.
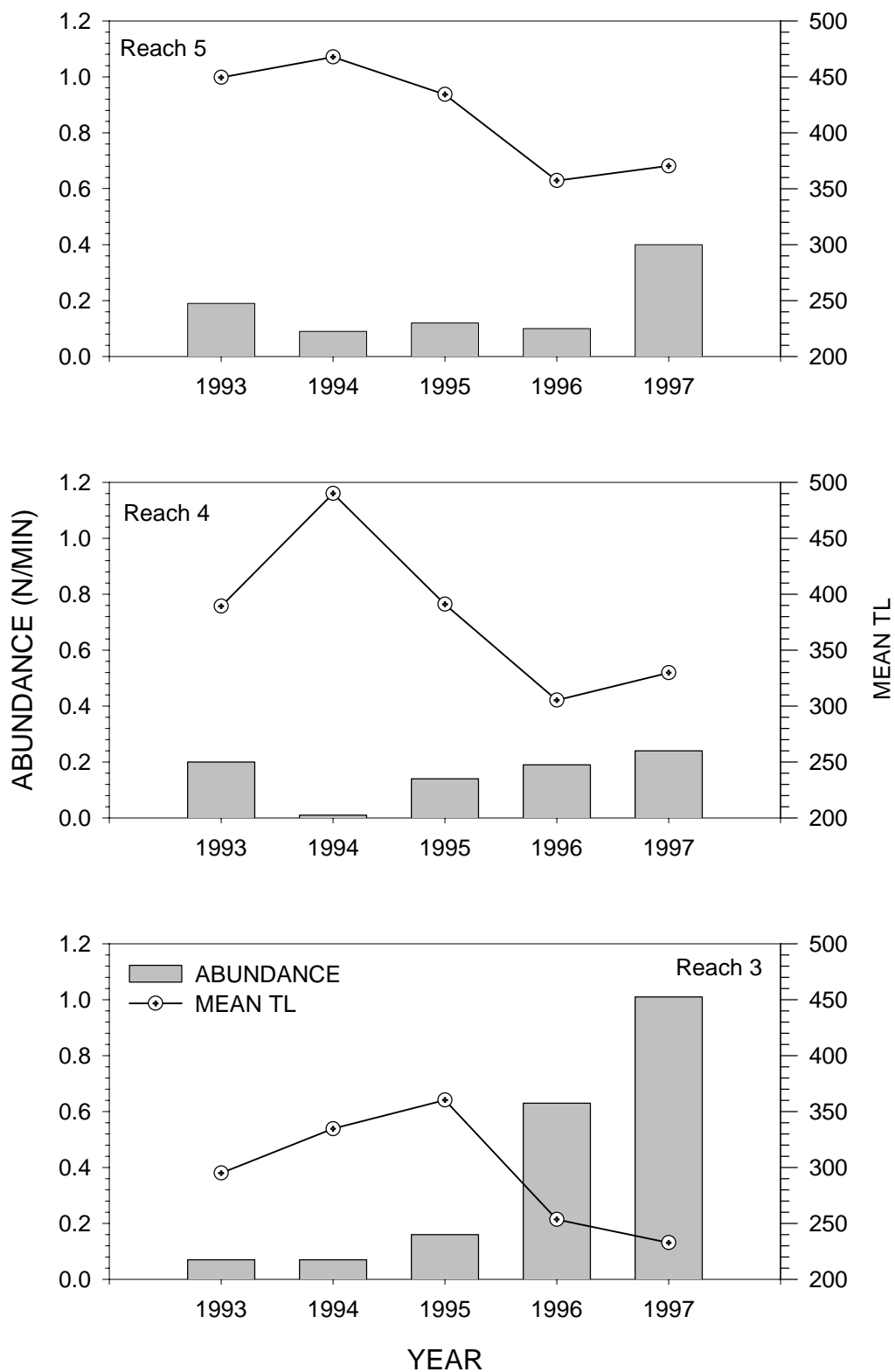
Figure 28. Abundance and mean total length of channel catfish, *Ictalurus punctatus*,
in San Juan River secondary channels during spring, 1993 - 1997.

but by 1997 their abundance declined to about 60% of the collection (Figure 30). Sub-adult (176 to 300 mm) abundance peaked in 1996.

In Reach 4, size-structure of the channel catfish population varied substantially from year-to-year (Figure 31). In addition to capture of more very large individuals (>550 mm TL) in this reach than other reaches, several fish <200 mm were captured in most years.

Table 10. Results of Kolomogorov-Smirnov (D_{max}) sequential comparisons of size-structure of channel catfish in San Juan River secondary channel collections, spring 1993 – 1997.

	YEARS	D_{MAX}	SIGNIFICANCE
GEOMORPHIC REACH 5	93 – 94	-0.2095	NS
	94 – 95	-0.1245	NS
	95 – 96	0.2436	NS
	96 – 97	0.2487	NS
GEOMORPHIC REACH 4	93 – 94	0.5929	<0.001
	94 – 95	-0.3656	NS
	95 – 96	0.3109	NS
	96 – 97	0.2417	NS
GEOMORPHIC REACH 3	93 – 94	-0.2036	NS
	94 – 95	-0.2174	NS
	95 – 96	0.1757	NS
	96 – 97	0.1739	NS

In 1994 only one channel catfish was collected. The size-structure of the 1993 sample was significantly different from the 1994 collection (Table 10), but the 1994 collection was not different from that of 1995. Abundance of channel catfish in Reach 4 varied little, excluding the 1994 collection, from year-to-year. Mean TL of channel catfish declined from 1993 through 1996 (again, excepting the 1994 collection), and increased slightly in 1997 (Figure 29). Adults were the most abundant age-class in all years, except 1996 when their abundance equaled that of sub-adults (Figure 32). Juveniles were found in more years in Reach 4 than 5.

Collections in Reach 3 yielded a higher proportion of small (<200 mm TL) catfish than were found in either upstream Reach, and abundance of large specimens (>400 mm) was typically less (Figure 33) than upstream reaches. In 1997, the 100 to 225 mm size-group represented over 50% of the collection. Sequential between-year comparisons of size-structure did not indicate significant differences (Table 10). Abundance of channel catfish in Reaches 5 and 4 remained fairly constant over the years of study, but steadily increased in Reach 3 (Figure 29). Abundance was <0.1 fish/min in 1993, but was slightly greater than 1.0 in 1997. While not as dramatic as abundance, changes in mean TL of channel catfish in Reach 3 were different from that observed in Reaches 5 and 4. Mean TL increased from 1993 through 1995 but declined from 1995 through 1997. By 1997, mean TL (233 mm) in Reach 3 was substantially less than in Reaches 5 and 4 (370 and 330 mm). Adults were the numerically dominant age-class in 1993 through 1995 (Figure 34), but juveniles and sub-adults were over 60% of the collections in 1996 and 1997.
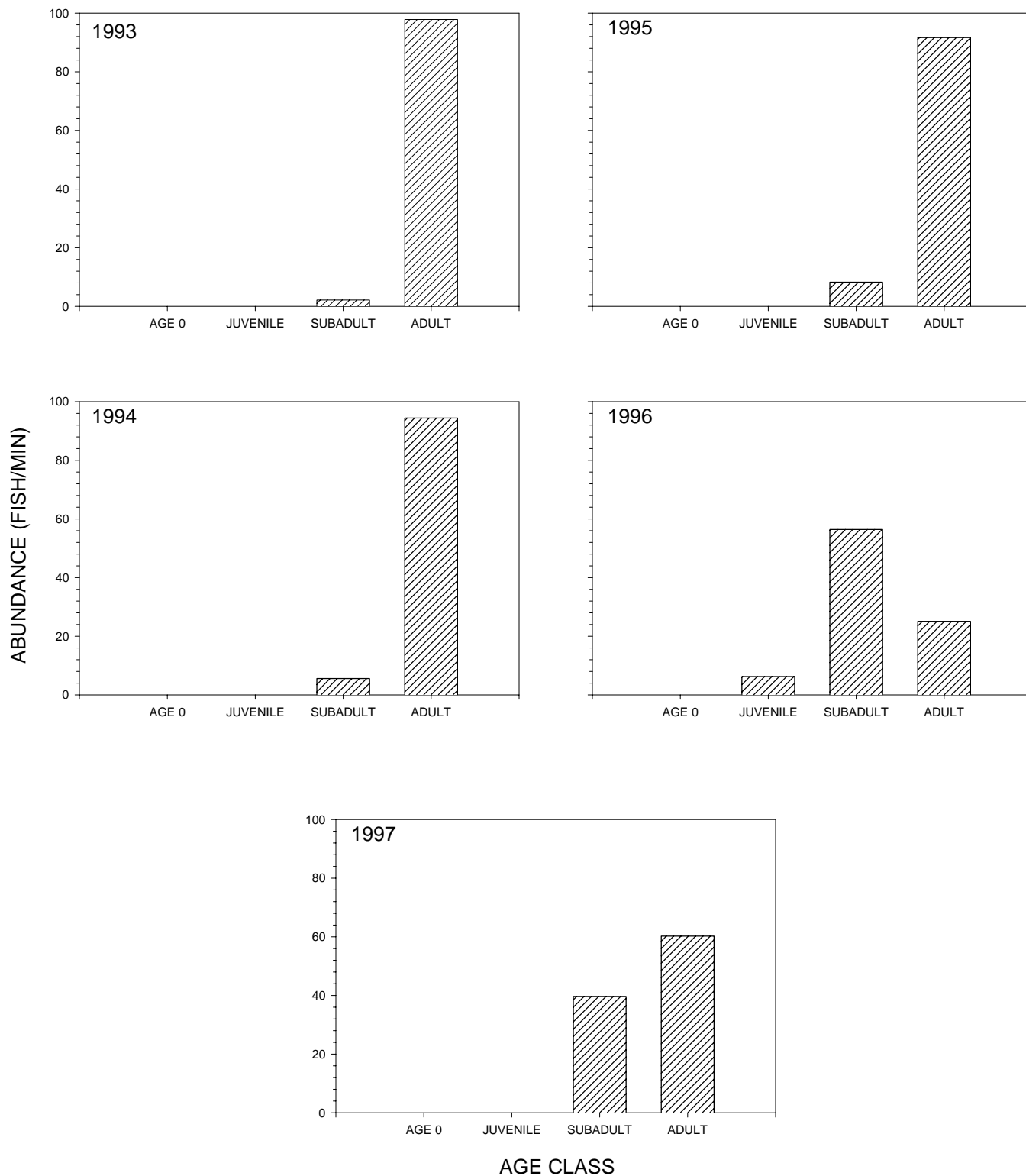
Figure 29. Age-structure of the channel catfish, *Ictalurus punctatus*,
population in Geomorphic Reach 5, San Juan River, 1993 - 1997.
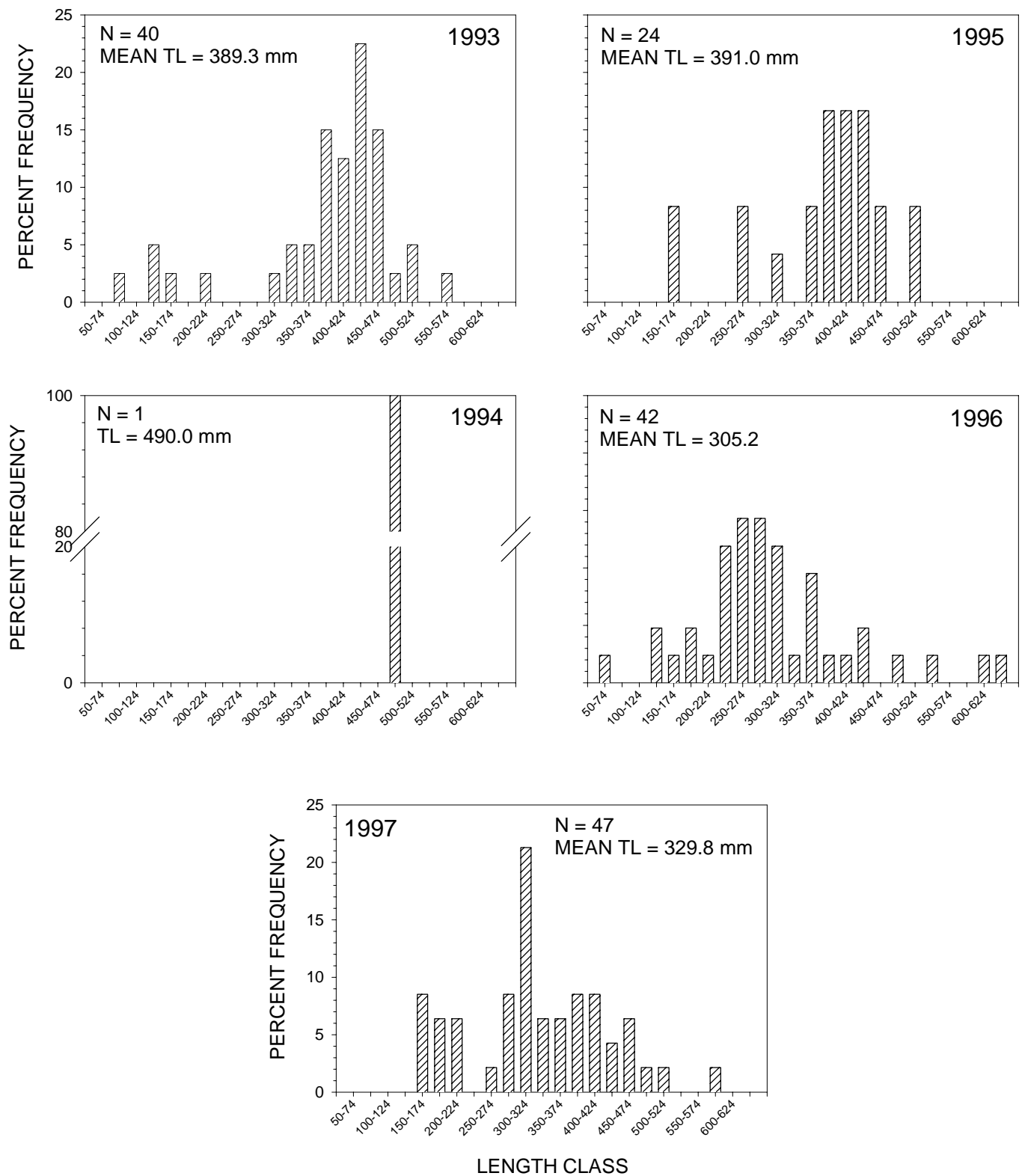
Figure 30. Size-structure of the channel catfish, *Ictalurus punctatus*,
population in Geomorphic Reach 4, San Juan River, 1993 - 1997.

49
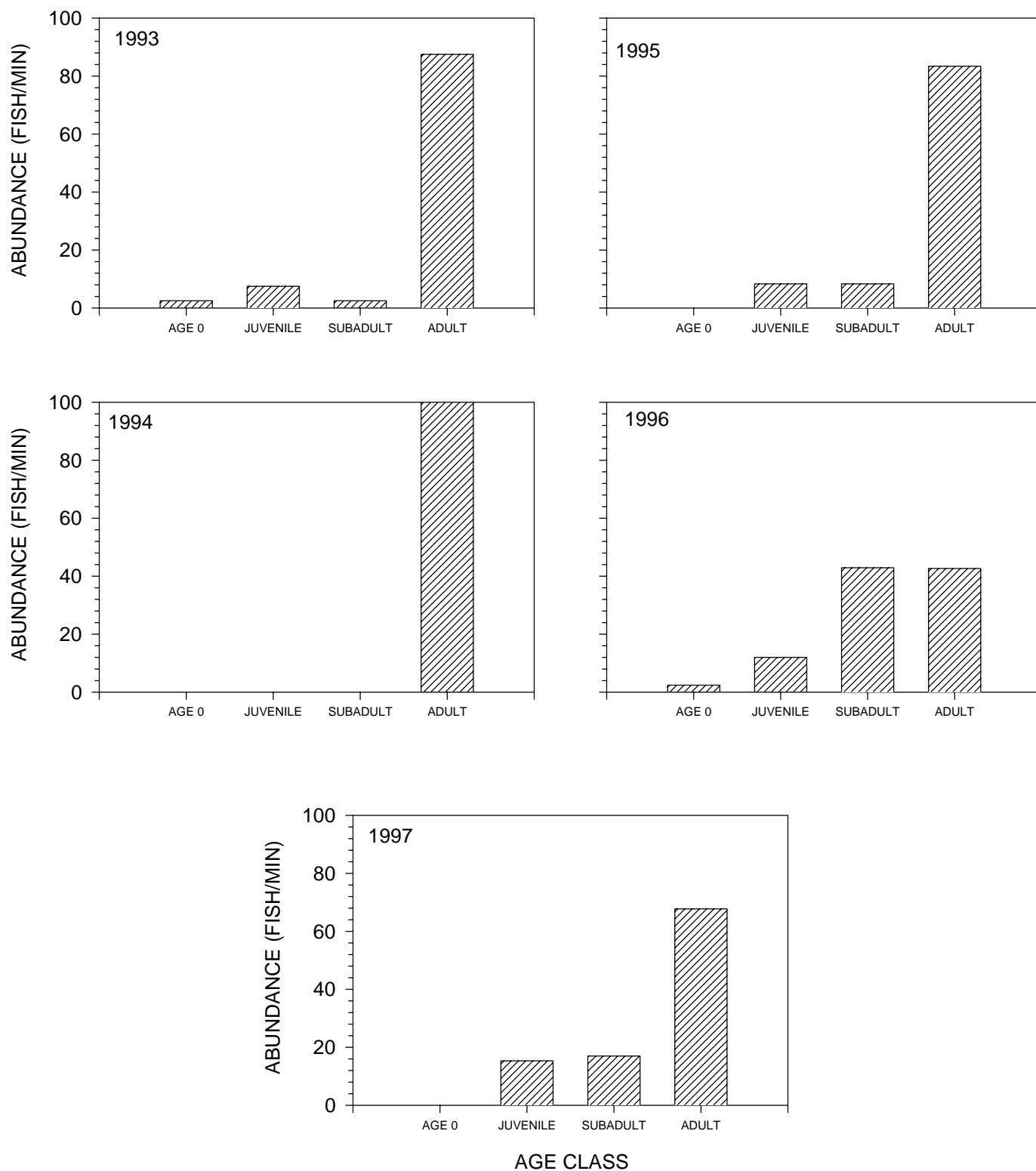
Figure 31. Age-structure of the channel catfish, *Ictalurus punctatus*,
population in Geomorphic Reach 4, San Juan River, 1993 - 1997.
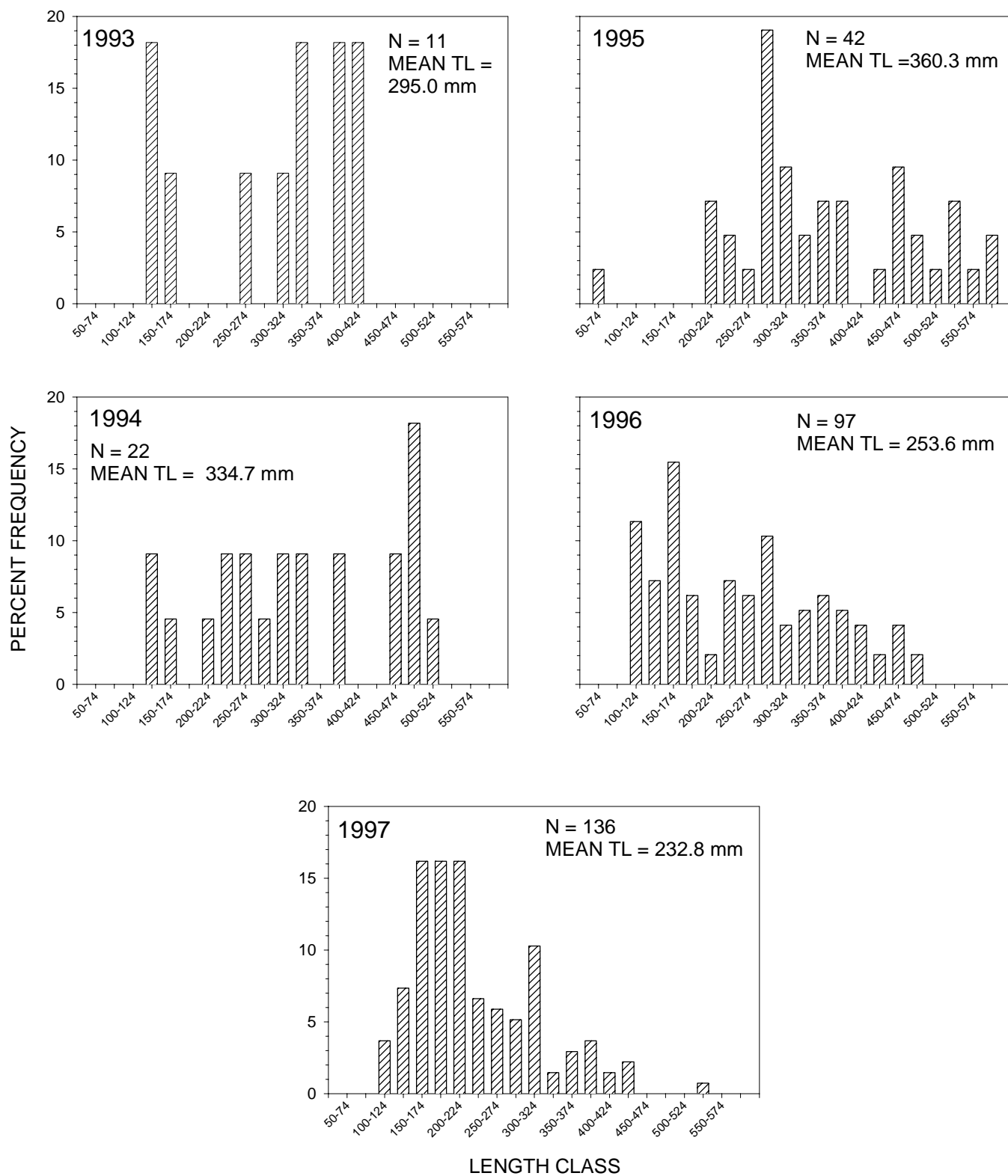
Figure 32. Size-structure of the channel catfish, *Ictalurus punctatus*,
population in Geomorphic Reach 3, San Juan River, 1993 - 1997.
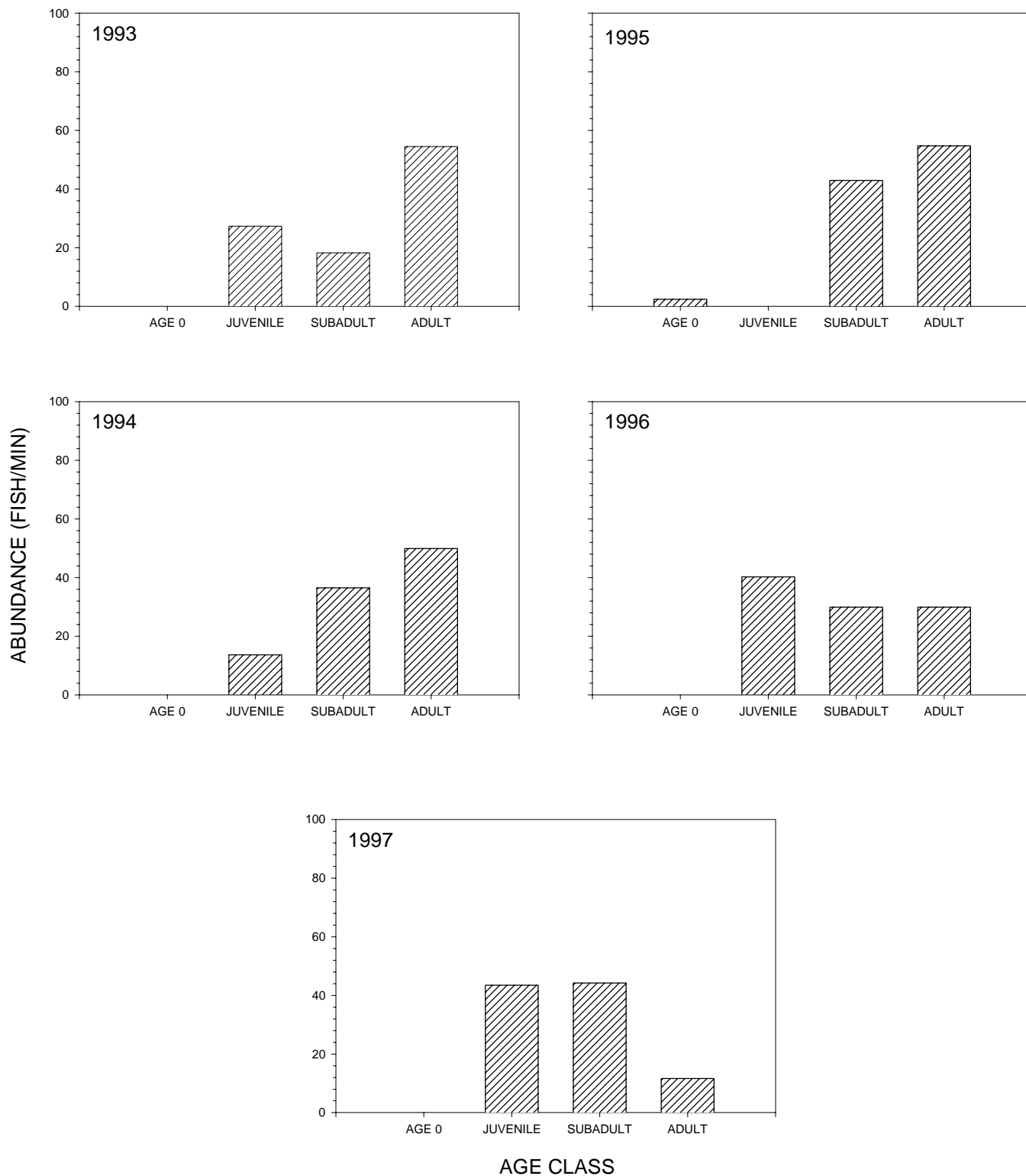
Figure 33. Age-structure of the channel catfish, *Ictalurus punctatus*,
population in Geomorphic Reach 3, San Juan River, 1993 - 1997.

Channel catfish abundance did not differ significantly among-years or reaches (F = 2.65, p = 0.112 and F = 1.90, p = 0.212). Among-reach differences in mean TL were significant (F = 26.25, p = 0.0003).

In Reach 5, channel catfish total biomass declined substantially from 1993 through 1996, but increased in 1997 (Figure 35). In Reaches 4 and 3, total biomass was fairly similar among most years. Mean biomass declined considerably from 1993 (1048 g) through 1997 (466 g) in Reach 5, noticeably in Reach 4 (688 to 378 g) and Reach 3 (261 to 161 g). Neither total nor mean biomass of channel catfish was significantly different among reaches (F = 0.74, p = 0.498 and F = 3.148, p = 0.080).

<u>Within Reach Species Biomass Comparisons</u>.

Significant differences in total biomass of species were found in all reaches. In Reach 5, total flannelmouth sucker biomass was greater than other species (F = 14.437, p = 0.0008). Post hoc tests indicated it was significantly greater than that of bluehead sucker and channel catfish, but not common carp (Table 11). Total biomass of common carp was significantly greater than bluehead sucker. Significant differences in total biomass also were found in Reach 4 (F = 35.865, p < 0.0001). Total biomass of flannelmouth sucker was significantly greater than other species, but differences among the latter were not significant. Differences in total biomass in Reach 3 were significant (F = 10.445, p = 0.0004) and similar to those found in Reach 5. Flannelmouth sucker total biomass was significantly greater than bluehead sucker and channel catfish, but not common carp. Common carp total biomass was significantly greater than bluehead sucker, but not channel catfish.

Mean biomass of common carp was greater than that of other species in all reaches. In Reach 5 differences in mean biomass were significant (F = 8.401, p = 0.001). Mean biomass of common carp was significantly greater than that of flannelmouth sucker and bluehead sucker, but not channel catfish. Mean biomass of channel catfish was significantly greater than bluehead sucker, but not flannelmouth sucker. Significant differences in mean biomass were also found in Reach 4 (F = 28.358, p < 0.0001); common carp was significantly larger than flannelmouth sucker, bluehead sucker, and channel catfish. Channel catfish mean biomass was significantly greater than that of bluehead sucker. Reach 3 mean biomass relationships (F = 19.887, p < 0.0001) were similar to those of Reach 4 with mean biomass of common carp being greater than that of bluehead sucker, flannelmouth sucker, and channel catfish. There were no significant differences among the latter three species.

Differences in abundance of species were significant for all reaches (Reach 5 F = 19.698, p < 0.0001; Reach 4 F = 40.963, p < 0.0001; and Reach 3 F = 23.019, p < 0.0001). Flannelmouth sucker was the most abundant species in all reaches. Its abundance was significantly greater than that of other species in all reaches (all $p \leq$ 0.004). Abundance of other species was not significantly different.
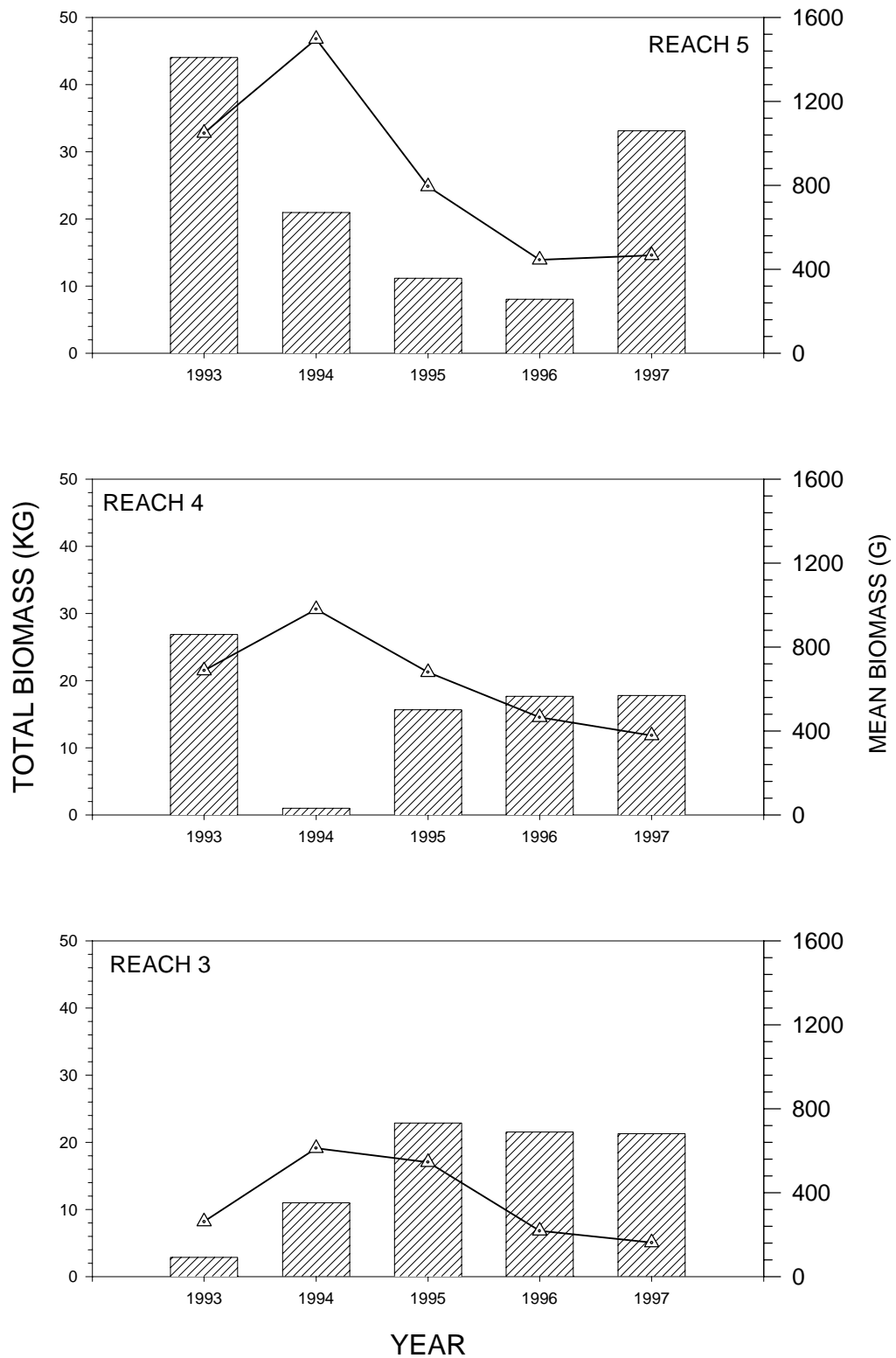
Figure 34. Biomass of channel catfish, *Ictalurus punctatus*, in San Juan River secondary channels during spring inventories, 1993 - 1997.

Table 11. Post hoc comparisons from ANOVA of total biomass (right of diagonal) and mean biomass (left of diagonal) of commonly collected fishes in San Juan River secondary channels during spring inventories. NS = not significant, * = $p \leq 0.05$, ** = $p \leq 0.01$, and *** = $p \leq 0.001$.

REACH 5

SPECIES	CATLAT	CATDIS	CYPCAR	ICTPUN
CATLAT	-----	***	NS	***
CATDIS	NS	-----	*	NS
CYPCAR	*	***	-----	NS
ICTPUN	NS	*	NS	-----

REACH 4

	CATLAT	CATDIS	CYPCAR	ICTPUN
CATLAT	-----	***	***	***
CATDIS	NS	-----	NS	NS
CYPCAR	***	***	-----	NS
ICTPUN	NS	*	***	-----

REACH 3

	CATLAT	CATDIS	CYPCAR	ICTPUN
CATLAT	-----	***	NS	**
CATDIS	NS	-----	*	NS
CYPCAR	***	***	-----	NS
ICTPUN	NS	NS	***	-----

Secondary and Primary Channel Comparisons

Between 1994 and 1997, spring inventories of primary and secondary channels were done concurrently, using the same sampling techniques (raft-mounted electrofishing). Data from primary and secondary channels were grouped by Geomorphic Reach; only primary channel data from designated miles were used while all data from all sampled secondary channels were used.

Mean biomass of flannelmouth sucker in primary and secondary channels was similar in all years and all reaches (F = 0.294, p = 0.593; reaches and years combined) (Figure 36). Flannelmouth sucker mean biomass (primary and secondary combined) was greater in Reach 5 than 4 and Reach 4 than 3 (F = 26.052, p < 0.001). Among year comparisons (primary and secondary combined), however, were not significantly different (F = 0.869, p = 0.474).

Abundance of flannelmouth sucker was significantly greater in secondary channels than the primary channel (Figure 37; F = 5.570, p = 0.028; years and reaches combined). Significant differences were also found for among year comparisons (F = 5.342, p = 0.007; reaches and channels combined). Post hoc tests indicated that the only significant yearly comparison was that between 1994 and 1997 (p = 0.005).
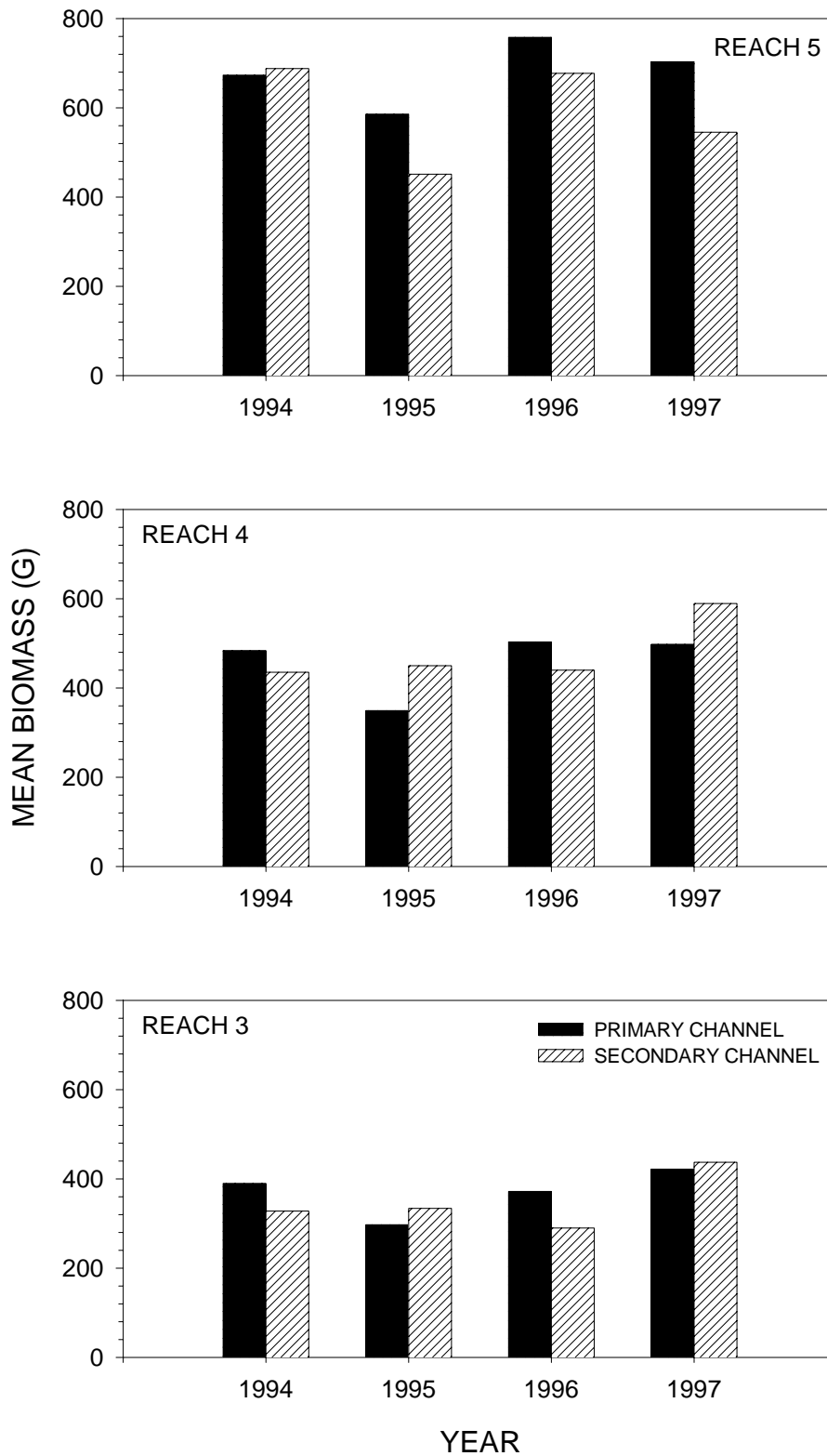
Figure 35. Mean biomass (g) of flannelmouth sucker, *Catostomus latipinnis*, in primary and secondary channels of the San Juan River, 1994 - 1997.
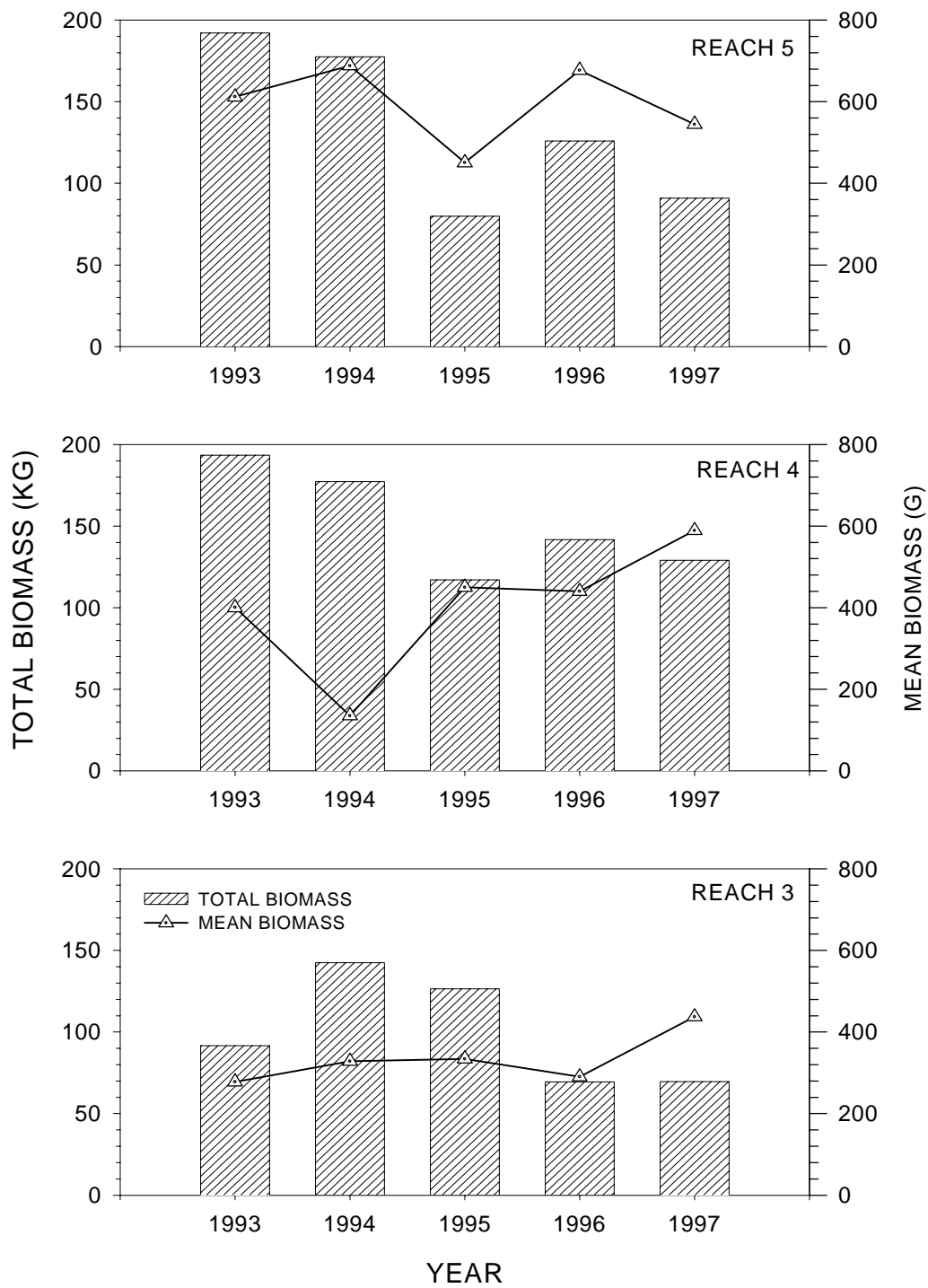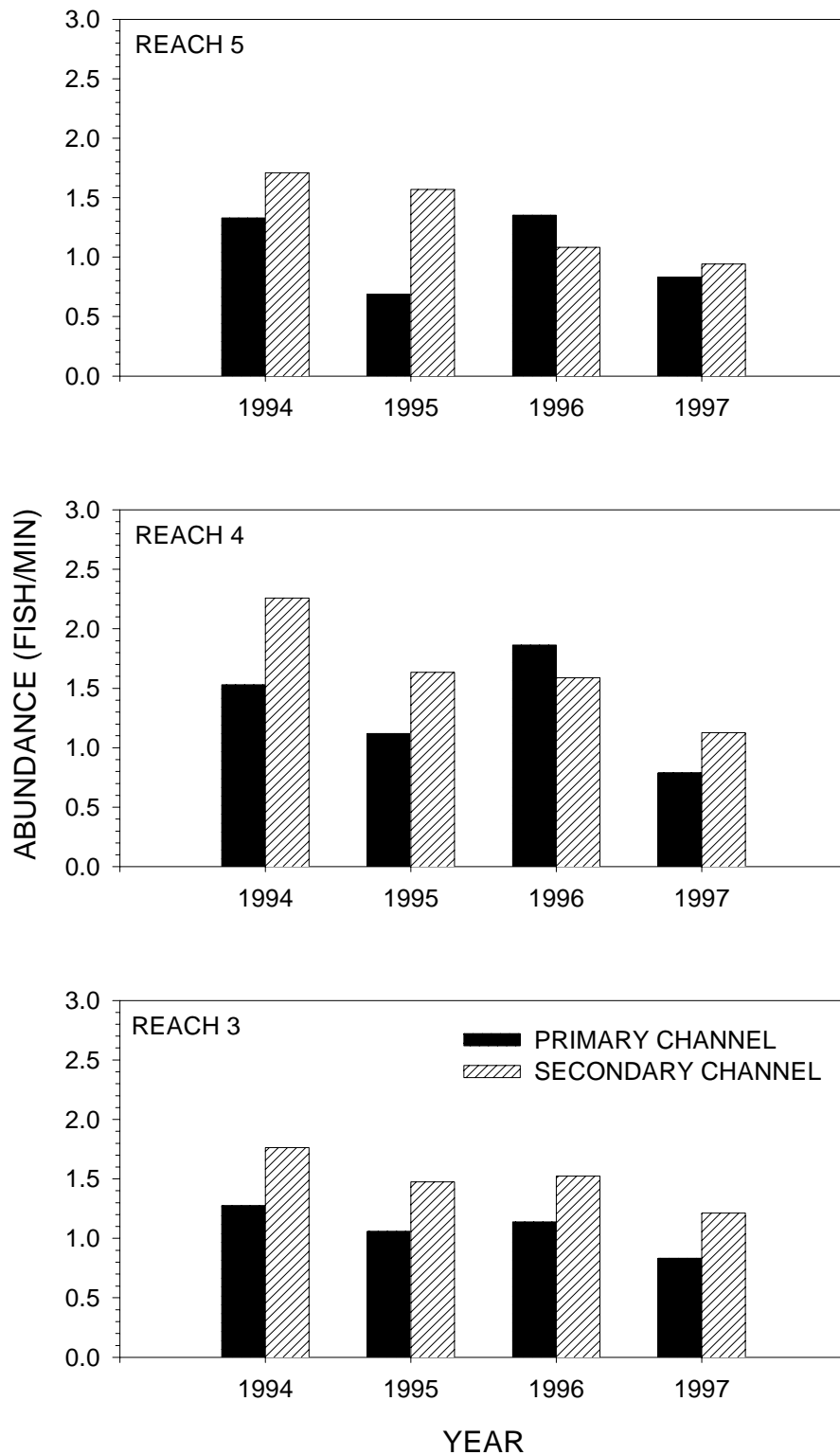
Figure 36. Abundance (fish/min) of flannelmouth sucker, *Catostomus latipinnis*, in San Juan River primary and secondary channels during spring inventories, 1994 - 1997.

Among reach differences (years and channels combined) were not significant (F = 1.300, p = 0.294).

Between 1994 and 1997, mean biomass of bluehead sucker increased in the primary but remained fairly constant in secondary channels in Reach 5. In Reaches 4 and 3, both primary and secondary channels mean biomass remained fairly constant (Figure 38). Between channel (years and reaches combined) and among years (channels and reaches combined) mean biomass differences were not significant (F = 0.230, p = 0.636 and F = 0.533, p = 0.665) but reach (channels and years combined) differences were (F = 7.862, p = 0.003). Post hoc tests revealed that mean biomass in Reach 5 was significantly greater than in Reach 4 (p = 0.003) and 3 (p = 0.003).

In Reach 5, abundance of bluehead sucker was usually greater in the primary than secondary channels. Generally, the differences in Reaches 4 and 3 were not great (Figure 39). Abundance was significantly greater in Reach 5 than Reach 4 than Reach 3 (F = 10.976, p = 0.0005). Between channel (years and reaches combined) and among year (channels and reaches combined) differences were not significant (F = 0.599, p = 0.447 and F = 1.428, p = 0.264).

There were no differences between primary and secondary channels in mean biomass of common carp (F = 3.632, p = 0.070; reaches and years combined), among reaches (F = 3.379, p = 0.053; channels and years combined), or among years (F = 0.114, p = 0.951; channels and reaches combined) comparisons (Figure 40). Of the abundance comparisons, only that among years yielded significant differences (F = 4.403, p = 0.016; channels and reaches combined). Abundance differences between channels (reaches and years combined) were apparent (Figure 41), but not significant (F = 3.656, p = 0.069). Abundance among reaches was similar (F = 0.817, p = 0.455).

Differences in mean biomass of channel catfish when compared among years and between channels were not significant (F = 3.013, p = 0.054 and F = 0.030, p = 0.865), but those among reaches were (F = 6.546, p = 0.006) (Figure 42). Post hoc tests indicated that mean biomass in Reach 5 (years and reaches combined) was significantly greater than in Reach 3 (p = 0.005). Abundance of channel catfish was not different in between channel (F = 1.071, p = 0.312) or among reaches (F = 3.019, p = 0.070) comparisons (Figure 43). Among year differences were significant (F = 4.937, p = 0.010); post hoc tests indicated that abundance (reaches and channels combined) in 1997 was greater than in 1994 and 1995 (p = 0.008 and 0.042).

Rare Fish Occurrence in Secondary Channels

Between 1993 and 1997, five specimens of rare fish were captured during spring inventories in secondary channels (Table 12). One Colorado pikeminnow was captured in 1994 in a secondary downstream of Sand Island, Utah. Four razorback suckers (all presumably stocked individuals) were captured in secondary channels between 1995 and 1997. All captures were between RM 95 and 108. No specimen of roundtail chub was captured in secondary channels during spring inventories between 1993 and 1997.

Table 12. Rare fishes captured in San Juan River secondary channels during spring inventories, 1993 – 1997.

SPECIES	DATE	RM	TL	SL	WT	SEX	TAG NUMBER
Ptychocheilus lucius	16 May 94	76.0	759	630	4000	F	7F7D075651
Xyrauchen texanus	13 May 95	87.0	372		600	F	1F404E666D
Xyrauchen texanus	17 May 96	107.8	420	340	910	M	1F40464E0D
Xyrauchen texanus	17 May 96	101.0	450	361	980	F	1F43670136
Xyrauchen texanus	4 May 97	95.8	434	345	850	M	1F40464E0D
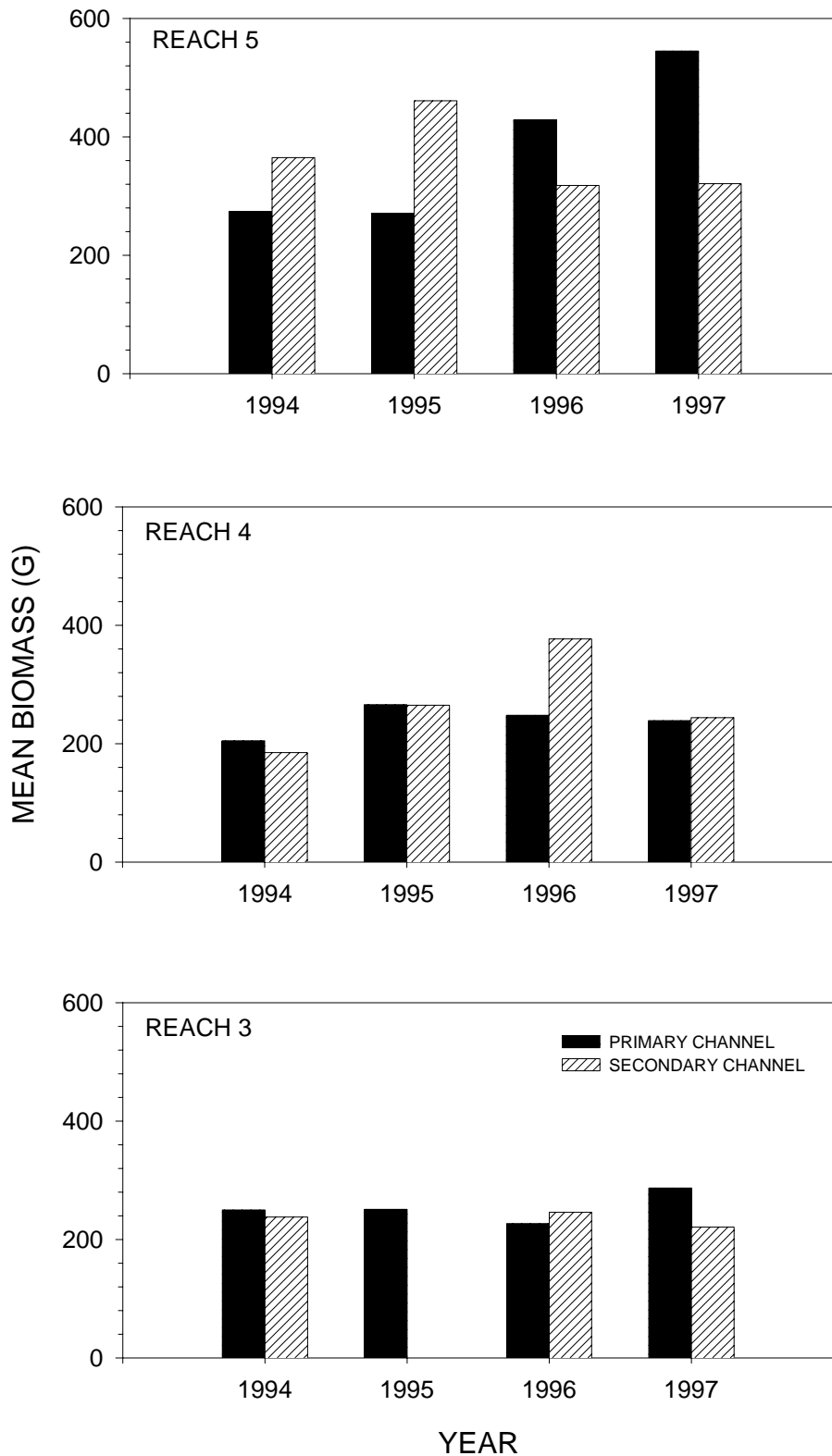
Figure 37 . Mean biomass (g) of bluehead sucker, *Catostomus discobolus*, in primary and secondary channels of the San Juan River, 1994 - 1997.
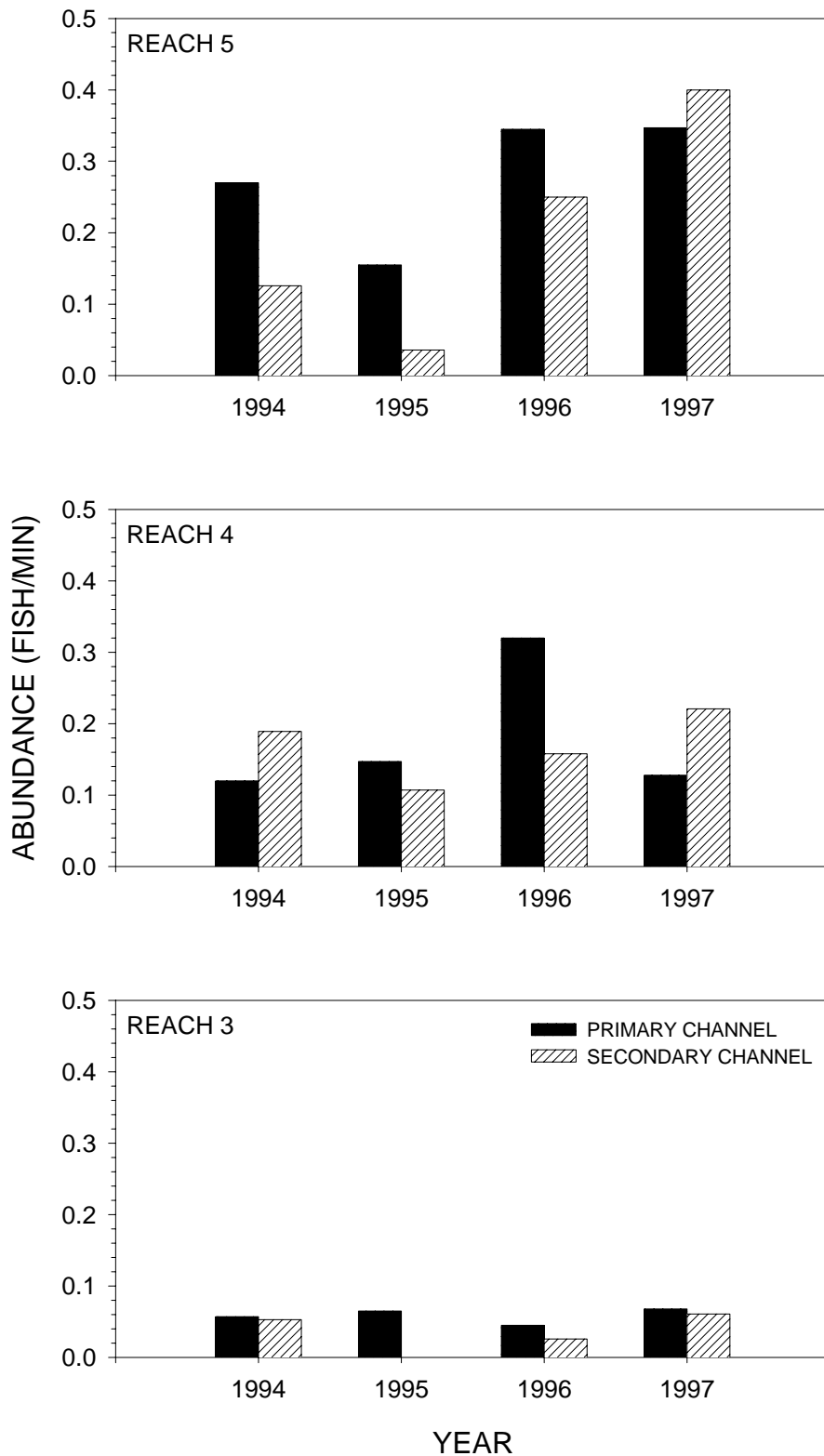
Figure 38. Abundance (fish/min) of bluehead sucker, *Catostomus discobolus*, in
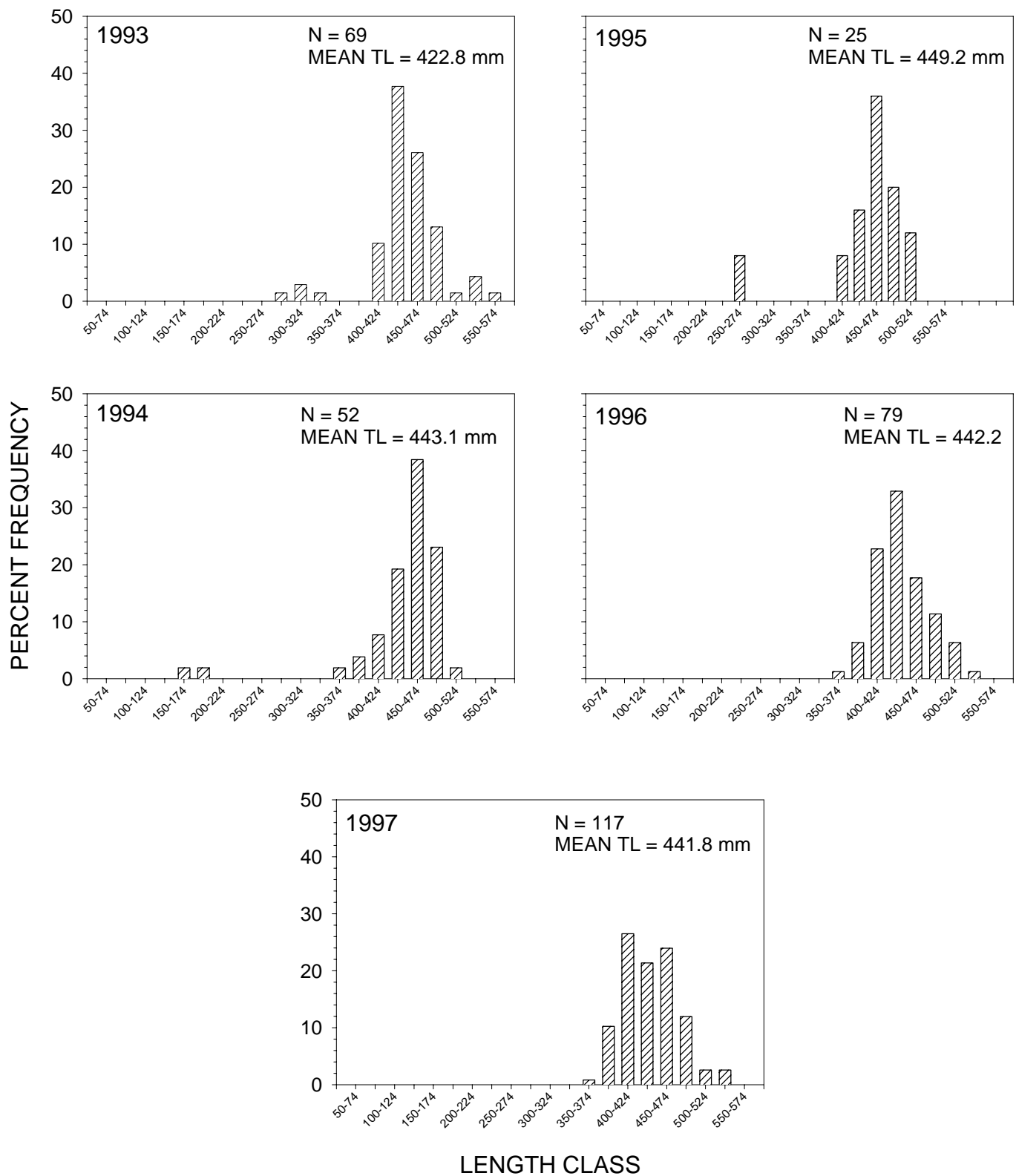San Juan River primary and secondary channels during spring
inventories, 1994 - 1997.
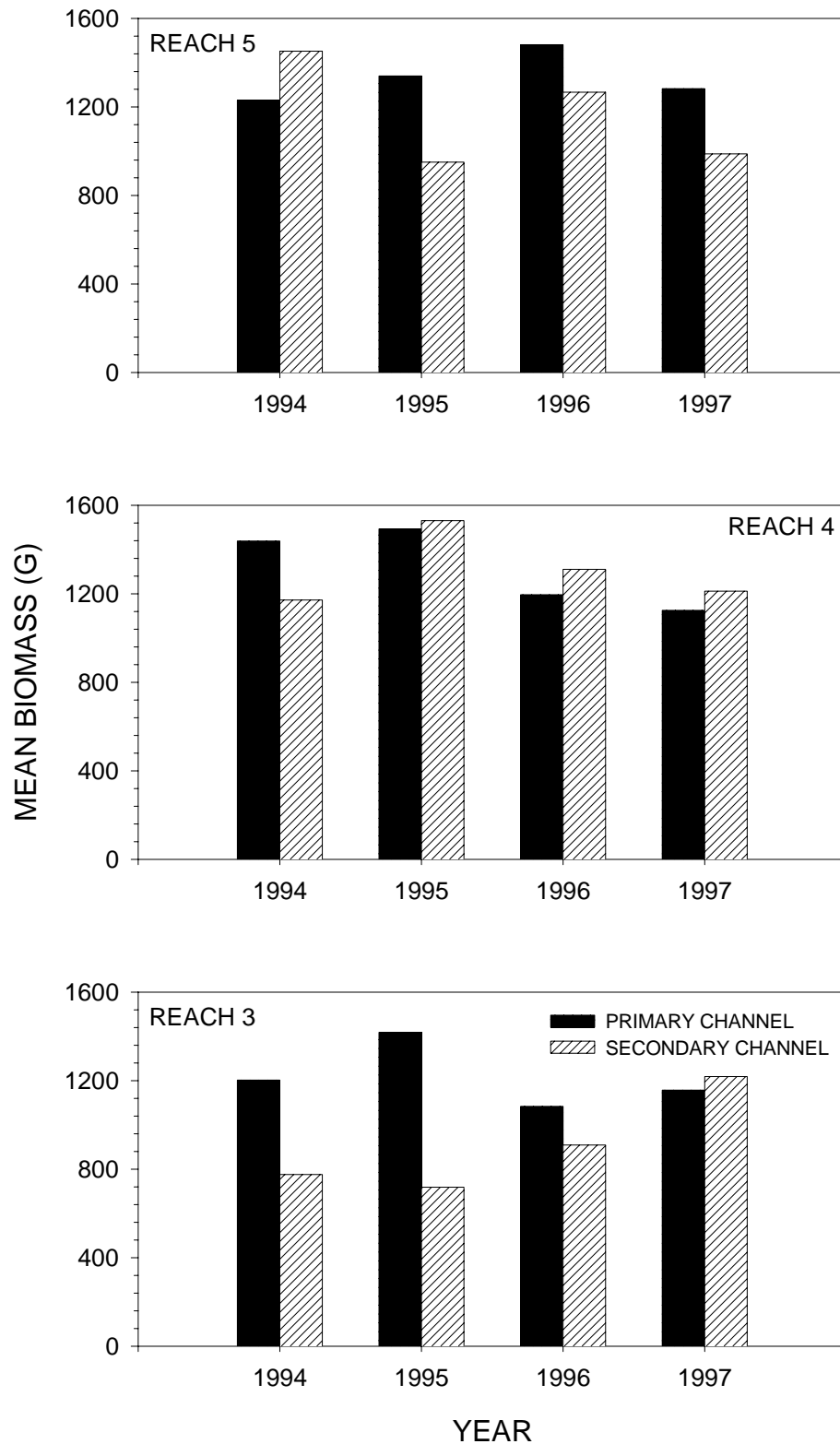
Figure 39 . Mean biomass (g) of common carp, *Cyprinus carpio,* in primary and secondary channels of the San Juan River, 1994 - 1997.
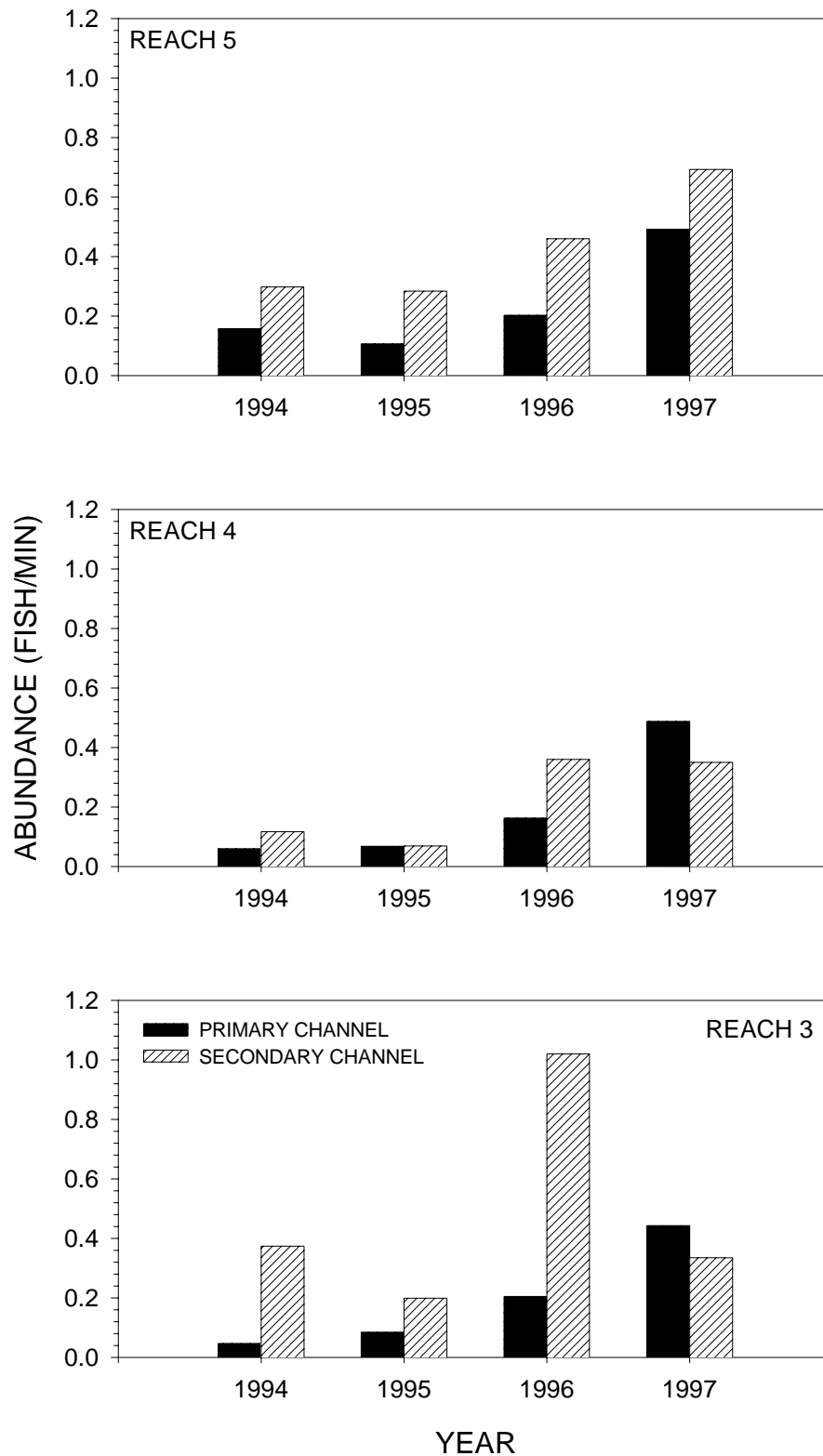
Figure 40. Abundance (fish/min) of common carp, *Cyprinus carpis*,
in San Juan River primary and secondary channels
during spring inventories, 1994 - 1997.
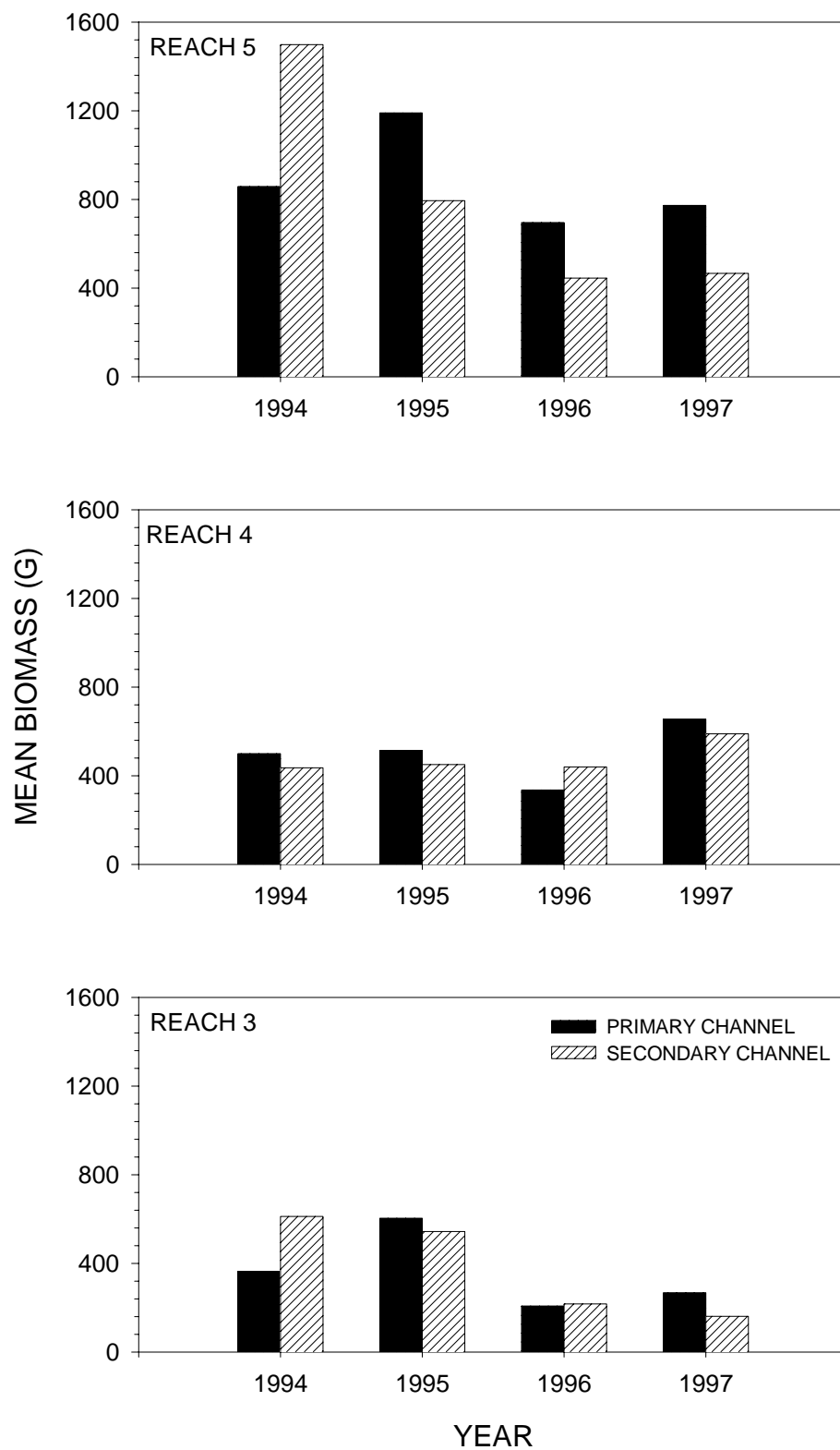
Figure 41. Mean biomass (g) of channel catfish, *Ictalurus punctatus*,
primary and secondary channels of the San Juan River, 1994 -
1997.
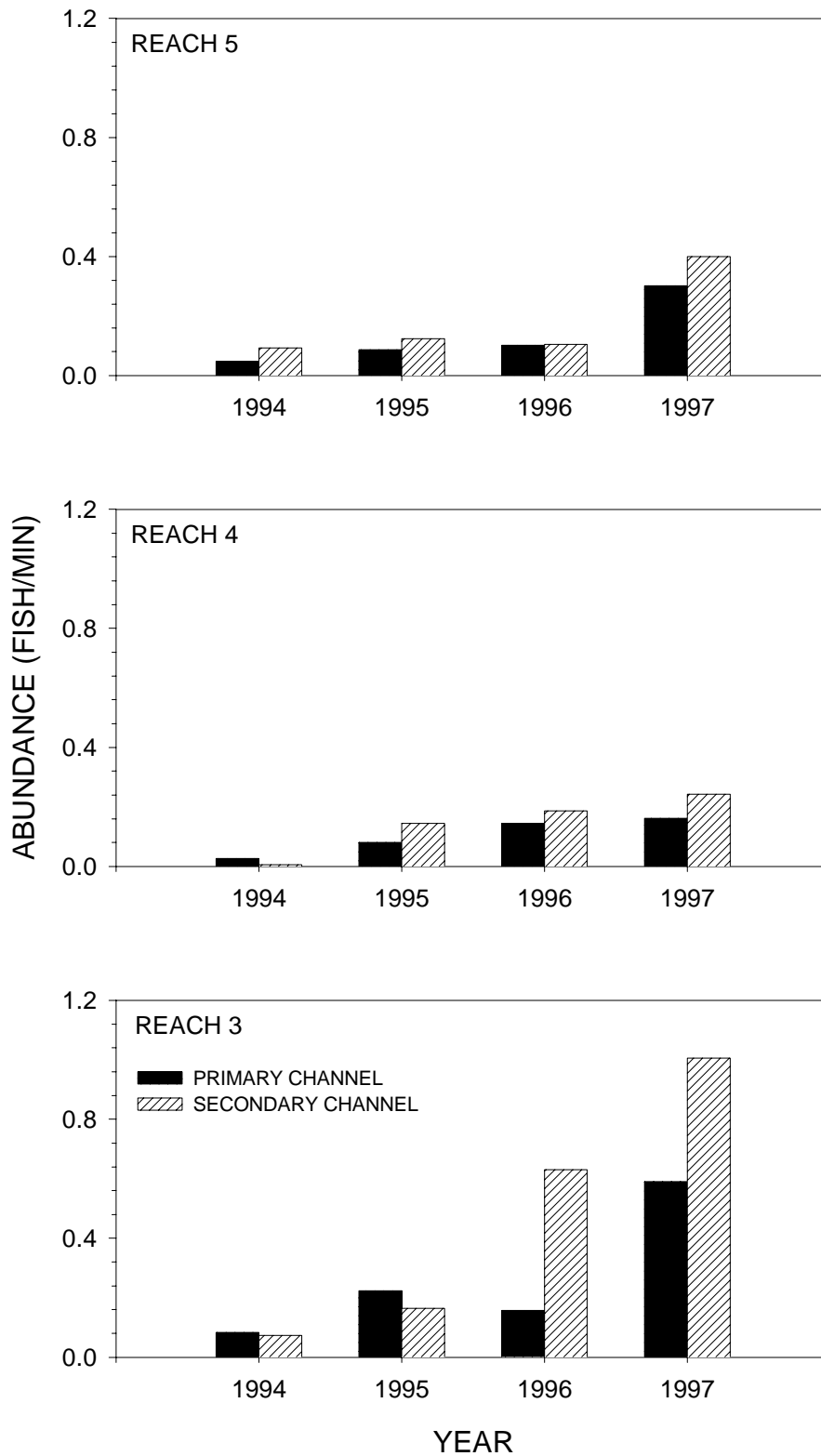
Figure 42. Abundance (fish/min) of channel catfish, *Ictalurus punctatus*, in San Juan River primary and secondary channels during spring inventories, 1994 - 1997.

FISH ASSEMBLAGES OF SAN JUAN RIVER

SECONDARY CHANNELS DURING SUMMER

1991 -- 1997

INTRODUCTION

During summer, San Juan River secondary channels do not have any habitat type that is absent in the primary channel, but some habitats that are relatively rare in the primary channel are fairly common in secondary channels. For example, during summer low- and zero-velocity pool habitats are common in many secondary channels. Habitat quantity and quality in secondary channels are dependent on flow levels, perhaps more so than in the primary channel. When flows are < 500 cfs, only about 50 % of the secondary channels are wetted (R. Bliesner, pers. comm.). During such periods, isolated pools with elevated water temperature and depressed dissolved oxygen are among the most abundant habitats available. Presumably, daily and seasonal changes in availability and quality of habitats have a strong influence on fish assemblages of secondary channels.

Objectives of the Secondary Channels Ichthyofaunal Inventory were:

1)   Characterize the type of secondary channels in the San Juan River;
2)   Characterize the faunal assemblages of secondary channels;
3)   Determine seasonal use patterns of secondary channels by target species; and
4)   Relate habitat use and availability of secondary channels to flow levels.

This phase of the Secondary Channels Study was designed to document the species occupying San Juan River secondary channels during summer low-flow periods and to characterize the effect of spring flow attributes on summer fish assemblages and abundance of individual species. This chapter specifically addresses study objectives 2 (in part), 3 (in part), and 4 (in part).

STUDY AREA

Summer sampling of San Juan River secondary channels occurred between RM 149.5 (Shiprock) and RM 76.5 (Sand Island). During summer low-flow periods, some secondary channels were dry for much of their lengths, others had scattered pools, sometimes connected by shallow rivulets, and a few had continuous surface flow for their entire lengths. Summer convectional storms sometimes raised water levels shortly before or during sampling and briefly inundated dry channels and connected pools in others. Some had inflow at their mouths and water persisted for variable distances downstream. Isolated pools in some were maintained by extrusion of subsurface water. About 50 % of the secondary channels in the study area had surface water at flows of 500 cfs and about 78 % were watered at 1500 cfs (R. Bliesner, pers. comm.). Summer flows during each year of study averaged from about 280 to 2010 cfs (Figure 44).
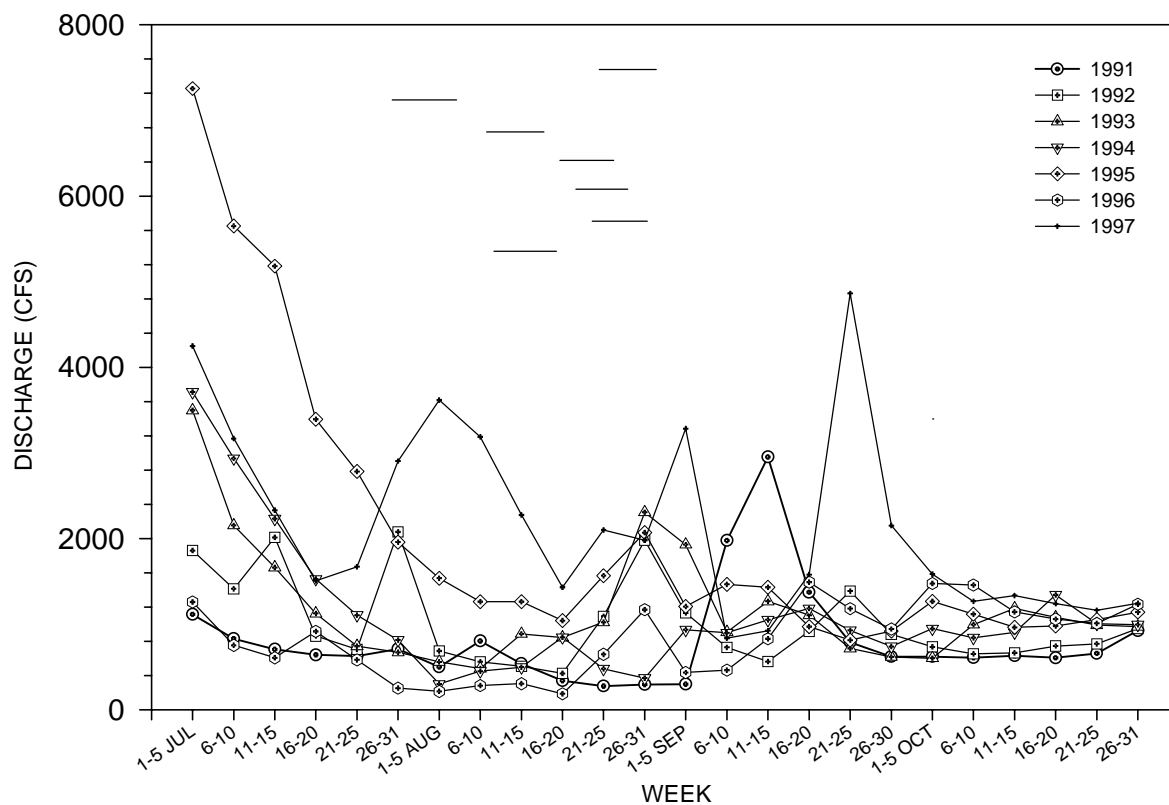
Figure 43. Mean weekly discharge of San Juan River, 1 July through 31 October, 1991 - 1997. Horizonal lines indicate time of summer sampling trips.

During summer, base substrates (cobble, gravel, and sand) were typically overlain with a silt layer of varying thickness (1 or 2 mm to 20 cm) in low-velocity areas. Riffles were usually the only silt-free habitats in secondary channels. Riparian vegetation shaded some secondary channels but others were completely exposed to sunlight.

Secondary channels having surface water one year were sometimes dry in subsequent years. Deposition of organic debris, along with silt and sand, during high flow periods precluded inflow to some channels and low flows resulted in drying of others. Within each secondary channel, the mix of habitats varied among years. A secondary channel with riffles, pools, and runs, all having silt-free substrates, might have only a few silt-bottomed isolated pools the next year.

METHODS

Summer sampling of San Juan River secondary channels between Shiprock 9RM 147.9) and Sand Island (RM 76.5) occurred during late-July through August, 1991 through 1997. In 1991 and 1992, only secondaries with surface inflow at their mouths were sampled. In subsequent years, the inflow requirement was discontinued and all secondary channels that had surface water, regardless of extent, were sampled. If surface water was limited to the embayment or backwater associated with the secondary channel's debouchement, it was not sampled as part of the secondary channel studies; these habitats were sampled under auspices of the Early Life History Studies portion of the San Juan River Seven-Year Research program (E. Archer, pers. comm).

Location of sample sites within secondary channels depended upon extent of surface water. If a secondary channel had surface flow throughout, the middle portion of it was sampled. If surface water consisted of scattered pools and short-flowing areas, collections were made wherever there was water. Regardless of the extent of surface water, all habitat types (e.g., pool, run, riffle, and backwater) present within the secondary channel were sampled.

Drag seines (3.1 x 1.8 m and 1.6 or 3.2 mm mesh) were used to collect fishes. In riffles, the seine was anchored across the wetted perimeter (or portion, depending upon width), perpendicular to direction of flow, and held by one individual. A second worker agitated the substrate from about 4 m upstream of the seine into the seine. Pools with debris piles were sampled by encircling the instream cover with the seine, agitating the cover, and lifting the seine. Other areas were sampled by dragging the seine parallel or diagonal to the shore; specific angle of the drag depended upon flow and substrate. In any case, the goal was to maximize efficiency of the drag. Area of each haul and kick effort was determined and recorded.

Large-bodied (> 150 mm Total Length [TL]) native fish were weighed ($\pm$ 1.0 g), measured ($\pm$ 1 mm TL), and released alive. All specimens in each seine haul were

examined to determine if roundtail chub, Colorado pikeminnow, or razorback sucker was present. If any of these was present, (individuals of these species < 75 mm TL were occasionally overlooked), it was weighed, measured, and released. All other specimens were preserved in 10 % formalin and returned to the laboratory for identification and enumeration. All specimens that could not be readily identified were sent to the Museum of Southwestern Biology (UNM) for identification. All retained specimens were accessioned to the NMGF Collection of Fishes. Six-letter codes (first 3 letters of genus and first 3 letters of species) were used to identify species in tables.

Following specimen collection, water quality was determined at a location not disturbed by specimen collection. Such areas were also a sufficient distance from the mouth of a secondary channel that primary channel influences were minimized. At each sampled secondary channel, water temperature (°C), dissolved oxygen (mg/l), and specific conductance (μmho/cm) were determined. General notes on habitat conditions for each sampled secondary channel were recorded.

Data from the USGS gage at Shiprock (#09368000) were used to characterize five attributes of spring runoff. The period of spring runoff was defined as 1 March through 31 July (R. Bliesner, pers. comm.). Mean spring runoff discharge (cfs) data for each year were provided by Keller-Bliesner Engineering, Inc. Monthly discharge data , spring runoff volume (ac-ft), days discharge > 3,000, 5,000, and 8,000 cfs were obtained from USGS Water Resources (New Mexico) Data Report (USGS, 1991 et seq.; Table 13). Although these attributes were covariant, each nonetheless provided slightly different metrics for assessing flow-related responses of fish populations.

For most analyses, the Geomorphic Reaches of Bliesner and Lamarra (2000) were used to group secondary channel data. Abundance was estimated as the number of individuals (total, by Geomorphic Reach, or species) captured per m^2 sampled. The Shannon-Wiener Diversity Index ($H = \Sigma p_I ln p_I$, where p_I = proportion of species i in the sample) was used to evaluate changes in assemblage structure (Ricklefs, 1979) among years and Geomorphic Reaches. Friedman's χ^2 and Kendall's coefficient of concordance (W; Zar, 1984) were used to evaluate changes in rank abundance of species; only those species collected in at least 5 of 7 years in each Geomorphic Reach were used. Regression analysis was used to assess the relationship between spring runoff attributes and summer abundance of six commonly collected species. These were native speckled dace, flannelmouth sucker, and bluehead sucker and nonnative red shiner, fathead minnow, and channel catfish. Although western mosquitofish was occasionally collected in large numbers, its occurrence was irregular and not deemed sufficient for meaningful analyses. Analysis of Variance (ANOVA) was used to evaluate differences in abundance and Shannon-Wiener Diversity Index values (Sokal and Rohlf, 1981) within Geomorphic Reaches (across years) and within a year (across reaches). The Tukey Honest Significant Difference test was used to determine which comparisons were different if ANOVA yielded significant results.

Table 13. Attributes of spring runoff, San Juan River, 1991 – 1997. Data from USGS Shiprock gage (#09368000).

MONTH	1991	1992	1993	1994	1995	1996	1997
MARCH[1]	1029	1258	5099	886	2777	700	2057
APRIL[1]	1750	3329	5970	868	3472	532	2295
MAY[1]	3515	6403	6387	4779	6108	1997	5703
JUNE[1]	2443	4757	6816	6563	9351	2661	8286
JULY[1]	885	1763	2438	3000	7193	789	3249
MEAN (CFS)[2]	2279	4083	6646	3592	5440	1607	4805
VOLUME (AC-FT)	555,308	1,004,618	1,539,529	790,550	1,523,378	355,850	1,203,366
DAYS > 3000 CFS	26	74	126	62	109	16	75
DAYS > 5000 CFS	0	45	101	43	72	0	44
DAYS > 8000 CFS	0	4	11	7	27	0	24

[1]Mean monthly discharge determined from USGS Water Year reports.
[2]Mean annual spring runoff discharge provided by Keller-Bliesner Engineering, Inc.

RESULTS

Summer secondary channel sampling occurred between RM 147.9 (Shiprock) and RM 76.5 (Sand Island) in all years except 1997 when secondary channels downstream to RM 68.7 (Chinle Creek) were sampled. All summer inventories were conducted during mid to late August, except 1992 when sampling as done in late July through early August. Sampling was post-spawning for native fishes (speckled dace, flannelmouth sucker, and bluehead sucker), but overlapped, in part, spawning by red shiner and fathead minnow. Comparatively few secondary channels were sampled in 1991 and 1992 (n = 21 and 13). In those years, inflow at top of secondary channel was required to sample it. In addition, flows were low (< 300 cfs) in 1991 at time of sampling and comparatively few secondary channels had water. Beginning in 1993, inflow at the mouth of a secondary channel was not required for it to be sampled. From 1993 through 1997, 33 to 45 secondary channels were sampled each year. Mean daily discharge during summer inventories varied from 278 (1991) to 2011 (1997) cfs.

Water Quality

Water temperature at time of summer inventories did not change appreciably from upstream to downstream in primary or secondary channels (Figure 45).
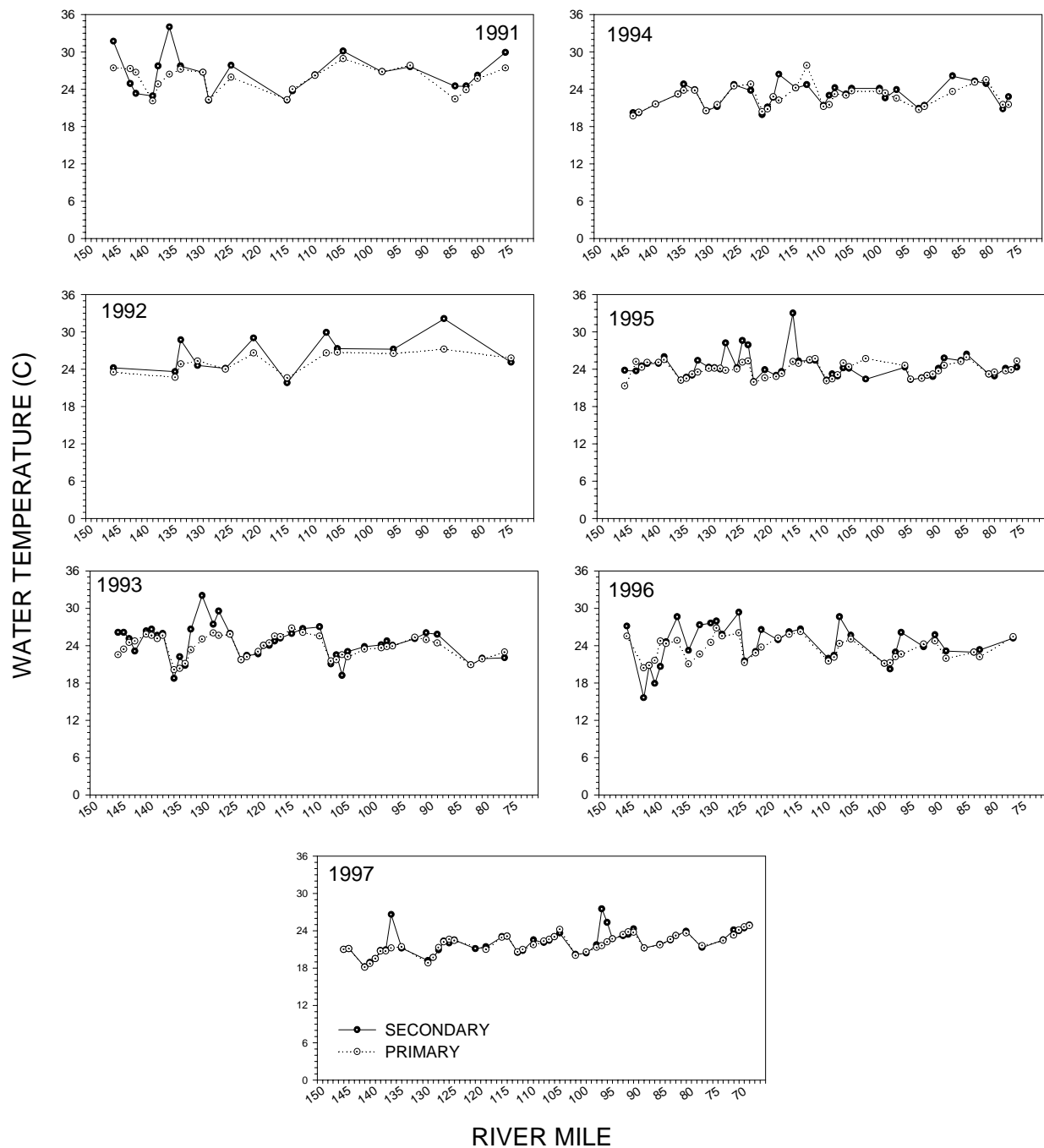
Figure 44. Water temperature (C°) of San Juan River secondary and primary channels during summer inventories, 1991 - 1997.

Secondary channel water temperature was usually similar to that of the adjacent primary channel; if different, temperature was greater in the secondary channel in most instances. Mean water temperature was > 21.0 and < 27.0° C in all years (Table 14). Dissolved oxygen generally declined from upstream to downstream in 1994, 1995, and 1996 in primary and secondary channels (Figure 46). Dissolved oxygen varied more among secondary channels than in the primary channel, particularly in 1993, 1994, and 1996. From 1991 through 1997, mean dissolved oxygen declined in both the primary and secondary channels (Table 14). In most years, differences in specific conductance between secondary and primary channels were negligible (Figure 47). Most differences occurred in 1994 and 1996; two differences in 1996 were considerable. The 1996 spikes were near Aneth and Montezuma Creek. Specific conductance tended to be lower in years of high summer flows and higher in years of low summer flows (Table 14). In 1991 and 1997, there was a slight increase in specific conductance from upstream to downstream, in 1993 an almost imperceptible decline, and no evident pattern in other years.

Table 14. Mean water quality parameters of San Juan River primary and secondary channels during summer inventories, 1991 – 1997. Parenthetic values are standard deviations.

YEAR	WATER TEMPERATURE (C°)		DISSOLVED OXYGEN (mg.l)		CONDUCTIVITY (µmho/cm)	
	1°	2°	1°	2°	1°	2°
1991	25.6 (2.1)	26.5 (3.2)	10.4 (0.9)	11.4 (2.1)	833 (134)	962 (362)
1992	25.2 (1.6)	26.5 (3.0)	10.6 (0.6)	11.0 (1.1)		
1993	23.8 (1.8)	24.4 (2.7)	8.9 (0.7)	8.3 (1.2)	722 (113)	783 (183)
1994	22.7 (1.8)	23.0 (1.8)	8.5 (1.6)	7.8 (2.4)	903 (110)	957 (127)
1995	23.9 (1.2)	24.4 (2.0)	6.4 (0.7)	6.3 (1.0)	586 (69)	601 (79)
1996	23.5 (1.9)	24.2 (3.2)	7.0 (0.7)	7.0 (1.1)	682 (72)	1230 (2190)
1997	21.9 (1.6)	22.2 (1.9)	6.2 (0.3)	6.2 (0.5)	432 (79)	448 (110)

Summer Fish Assemblages

A total of 14 species (five native and nine nonnative) were collected during summer inventories (Table 15). The greatest number of species (n = 11) was collected in 1991 and 1995 and the fewest (n = 9) in 1993. Number of native species (n = 5) was greatest in 1997 and fewest nonnative species (n = 6) were found in 1993 and 1997. The increase in number of native species in 1997 was the result of capture of rare roundtail chub and stocked Colorado pikeminnow. Five nonnative species (common carp, red shiner, fathead minnow, channel catfish, and western mosquitofish) and three native species (speckled dace, flannelmouth sucker, and bluehead sucker) were captured in all years of study. Few sub-adult or adult flannelmouth sucker, bluehead sucker, common carp, or channel catfish were collected. All age-classes (young-of-year, juvenile, sub-adult, and adult) of red shiner, fathead minnow, and speckled dace were collected; YOY
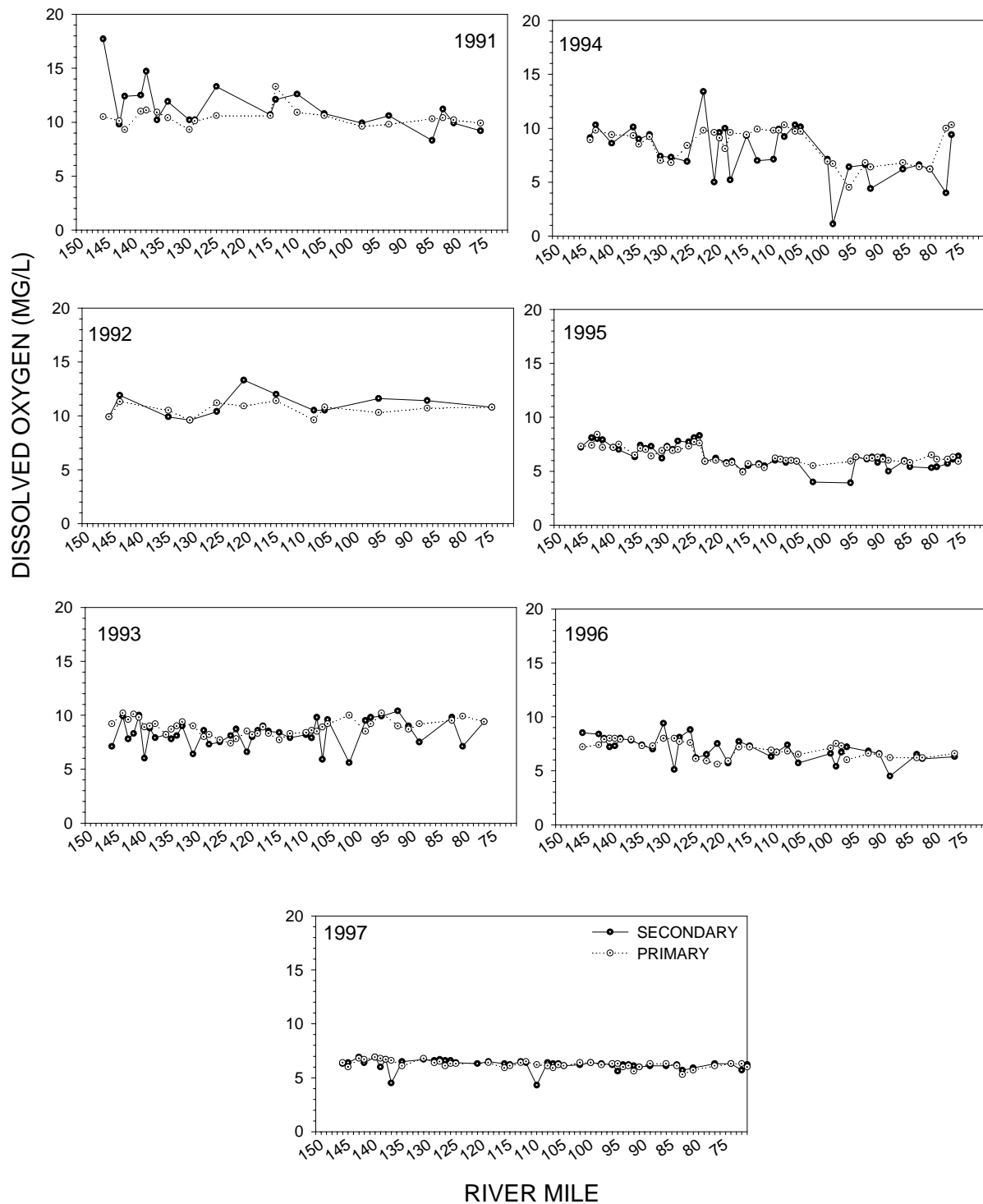
Figure 45. Dissolved oxygen (mg/l) of San Juan River secondary and primary channels during summer inventories, 1991 - 1997.
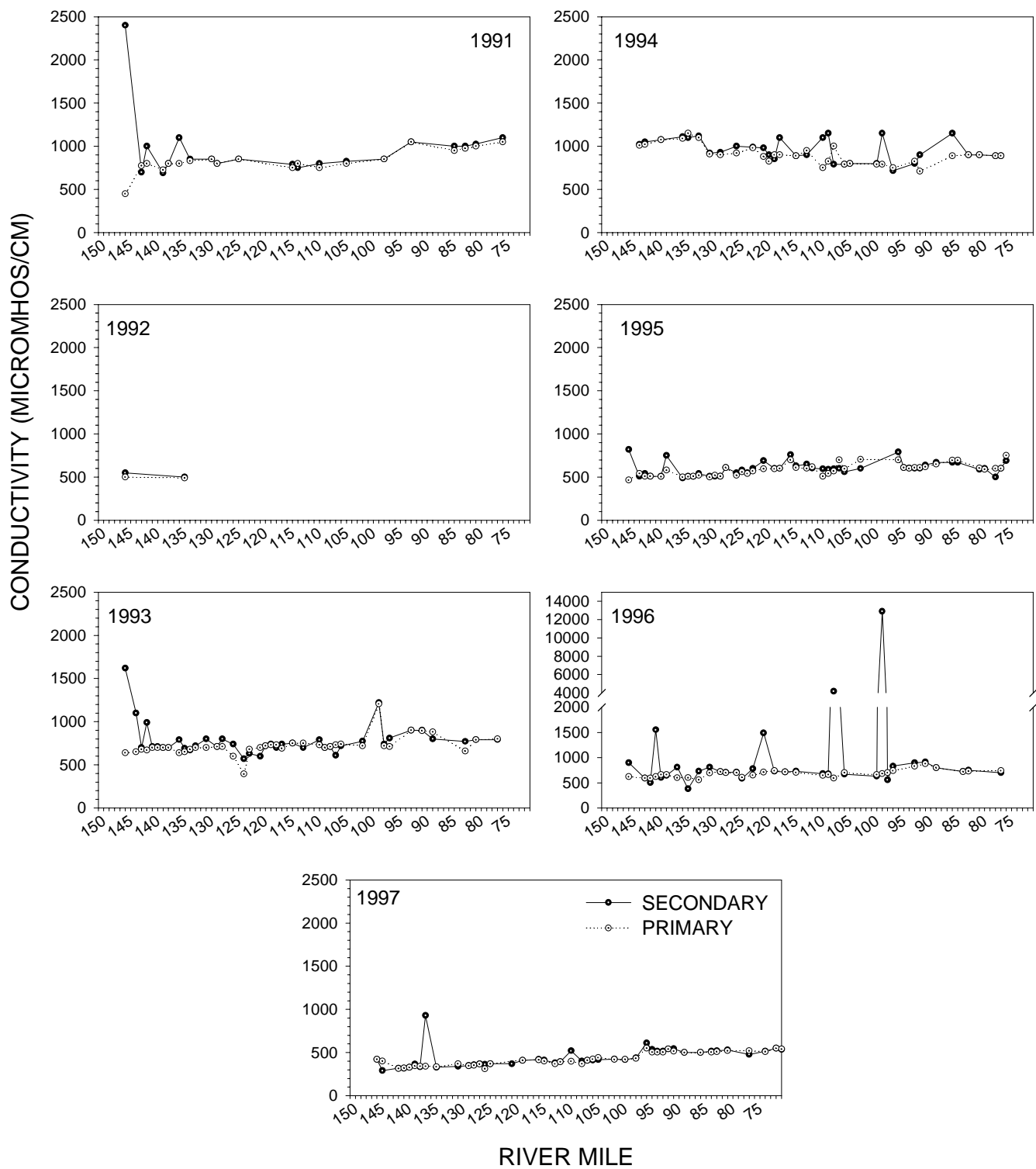
Figure 46. Specific conductance (micromhos/cm) of San Juan River secondary and primary channels during summer inventories, 1991 - 1997.

Table 15. Occurrence of fishes in San Juan River secondary channels during summer, 1991 – 1997. I = introduced and N = native. Six letter species codes derived from first three letters of genus and first three of species.

COMMON	SCIENTIFIC	ACRONYM	STATUS	1991	1992	1993	1994	1995	1996	1997
Common carp	*Cyprinus carpio*	CYPCAR	I	X	X	X	X	X	X	X
Red shiner	*Cyprinus lutrensis*	CYPLUT	I	X	X	X	X	X	X	X
Roundtail chub	*Gila robusta*	GILROB	N							X
Fathead minnow	*Pimephales promelas*	PIMPRO	I	X	X	X	X	X	X	X
Colorado pikeminnow	*Ptychocheilus lucius*	PTYLUC	N							X
Speckled dace	*Rhinichthys osculus*	RHIOSC	N	X	X	X	X	X	X	X
Flannelmouth sucker	*Catostomus latipinnis*	CATLAT	N	X	X	X	X	X	X	X
Bluehead sucker	*Catostomus discobolus*	CATDIS	N	X	X	X	X	X	X	X
Black bullhead	*Ameiurus melas*	AMEMEL	I						X	X
Channel catfish	*Ictalurus punctatus*	ICTPUN	I	X	X	X	X	X	X	X
Plains killifish	*Fundulus zebrinus*	FUNZEB	I	X	X		X	X	X	
Western mosquitofish	*Gambusia affinis*	GAMAFF	I	X	X	X	X	X	X	X
Green sunfish	*Lepomis cyanellus*	LEPCYA	I	X	X			X	X	
Largemouth bass	*Micropterus salmoides*	MICSAL	I	X		X	X	X	X	
Total Native				5	3	3	3	3	3	5
Total Nonnative				9	8	7	6	7	8	6

individuals were typically the most abundant age-class of these species. Most captured flannelmouth sucker and bluehead sucker were juveniles (25 to 100 mm TL).

Nonnative red shiner was the most abundant species in secondary channels in all years except 1994 and 1996 when nonnative fathead minnow was most common (Table 16). Abundance of other nonnative species was low in most years; however, channel catfish was moderately abundant in 1994 and western mosquitofish was common in 1996. Native speckled dace was the second- or third-most abundant species in all years. In 1991 and 1992, flannelmouth sucker was moderately common, but in subsequent years it was a relatively small proportion of the total collection (Figure 48). Bluehead sucker abundance was comparatively high in 1993 and 1995. Roundtail chub and Colorado pikeminnow were collected in 1997. Despite some shifts in the abundance rank of species, there was a high degree of concordance in ranks among years (W = 0.849, $p <$ 0.001).

Among years, total abundance varied considerably. Total abundance was high in 1993 and 1995 (> 12 fish/m^2), but was only 0.74 fish/m^2 in 1997 (Figure 49). The restriction of sampling to only those secondary channels with inflow in 1991 and 1992 may have contributed to the comparatively low fish abundance (< 3.0 fish/m^2) in those years. Shannon-Wiener Diversity Index values varied little from year to year (Figure 49). The highest values were in 1992 and 1994. There was no relationship between discharge during sampling periods and total fish abundance per sampling period ($r^2 = 0.079$, $p = 0.541$).
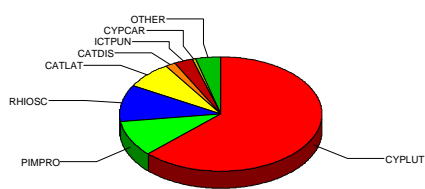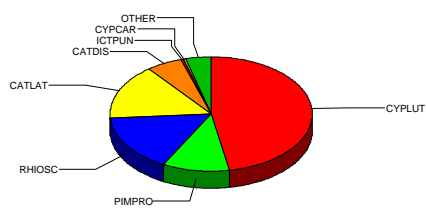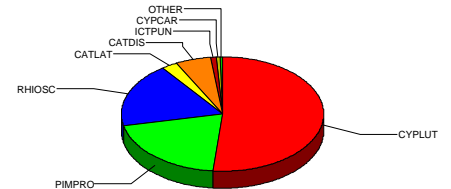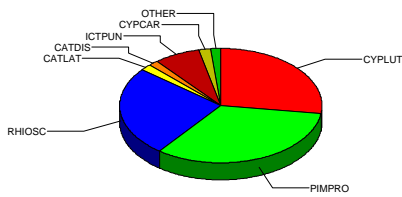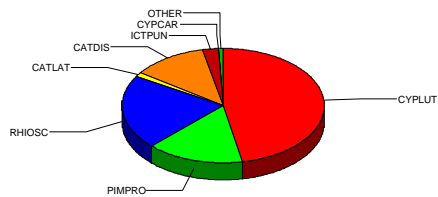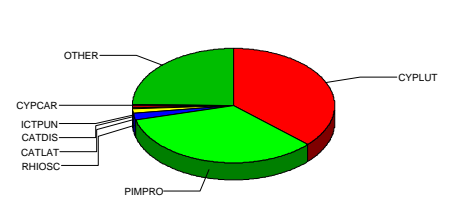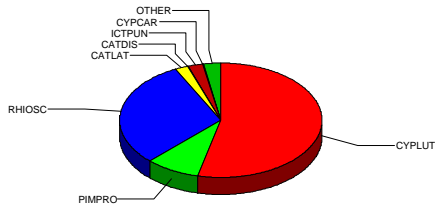
Figure 47. Relative abundance of commonly collected fishes in San Juan River
secondary channels (Reaches combined) during summer 1991 – 1997.

Table 16. Fish species collected in San Juan River secondary channels (RM 149 – RM 76.5) during summer inventories, 1991 – 1997. Bold-lettered species were used to calculate Kendall's coefficient of concordance (W).

1991		1992		1993		1994	
SPECIES	N	SPECIES	N	SPECIES	N	SPECIES	N
CYPLUT	1373	*CYPLUT*	728	*CYPLUT*	14034	*PIMPRO*	3721
RHIOSC	228	**RHIOSC**	249	**PIMPRO**	5516	**CYPLUT**	3073
PIMPRO	221	**CATLAT**	239	**RHIOSC**	4957	**RHIOSC**	2852
CATLAT	163	**PIMPRO**	166	**CATDIS**	1529	**ICTPUN**	830
GAMAFF	84	**CATDIS**	88	**CATLAT**	701	**CYPCAR**	210
ICTPUN	66	**GAMAFF**	47	**ICTPUN**	248	**CATLAT**	203
CATDIS	34	**FUNZEB**	15	**CYPCAR**	170	**GAMAFF**	171
CYPCAR	10	**ICTPUN**	7	**GAMAFF**	115	**CATDIS**	166
FUNZEB	3	**CYPCAR**	5	**MICSAL**	3	**FUNZEB**	16
MICSAL	3	LEPCYA	2			**MICSAL**	2
LEPCYA	2						
TOTAL N	2187		1546		27273		11244
AREA	928		680		1456		1344
ABUND	2.357		2.274		15.297		8.366

1995		1996		1997	
SPECIES	N	SPECIES	N	SPECIES	N
CYPLUT	12841	*PIMPRO*	2985	*CYPLUT*	1335
RHIOSC	5725	**CYPLUT**	3243	**RHIOSC**	751
PIMPRO	4218	**GAMAFF**	946	**PIMPRO**	215
CATDIS	3262	AMEMEL	192	**ICTPUN**	57
ICTPUN	692	*RHIOSC*	178	**GAMAFF**	56
CATLAT	366	**CATLAT**	108	**CATLAT**	50
GAMAFF	168	**ICTPUN**	63	AMEMEL	8
CYPCAR	18	**FUNZEB**	30	GILROB	5
MICSAL	11	**CATDIS**	28	*CATDIS*	4
FUNZEB	6	**CYPCAR**	5	**CYPCAR**	2
LEPCYA	2	**MICSAL**	3	PTYLUC	1
		LEPCYA	1		
TOTAL N	27309		8782		2484
AREA	2240		1296		3355
ABUND	12.195		6.776		0.740

Geomorphic Reach 5

Eleven species, eight nonnative and three native, were collected from secondary channels in Reach 5 between 1991 and 1997. Neither Colorado pikeminnow nor razorback sucker was collected. Total abundance and abundance of each species varied
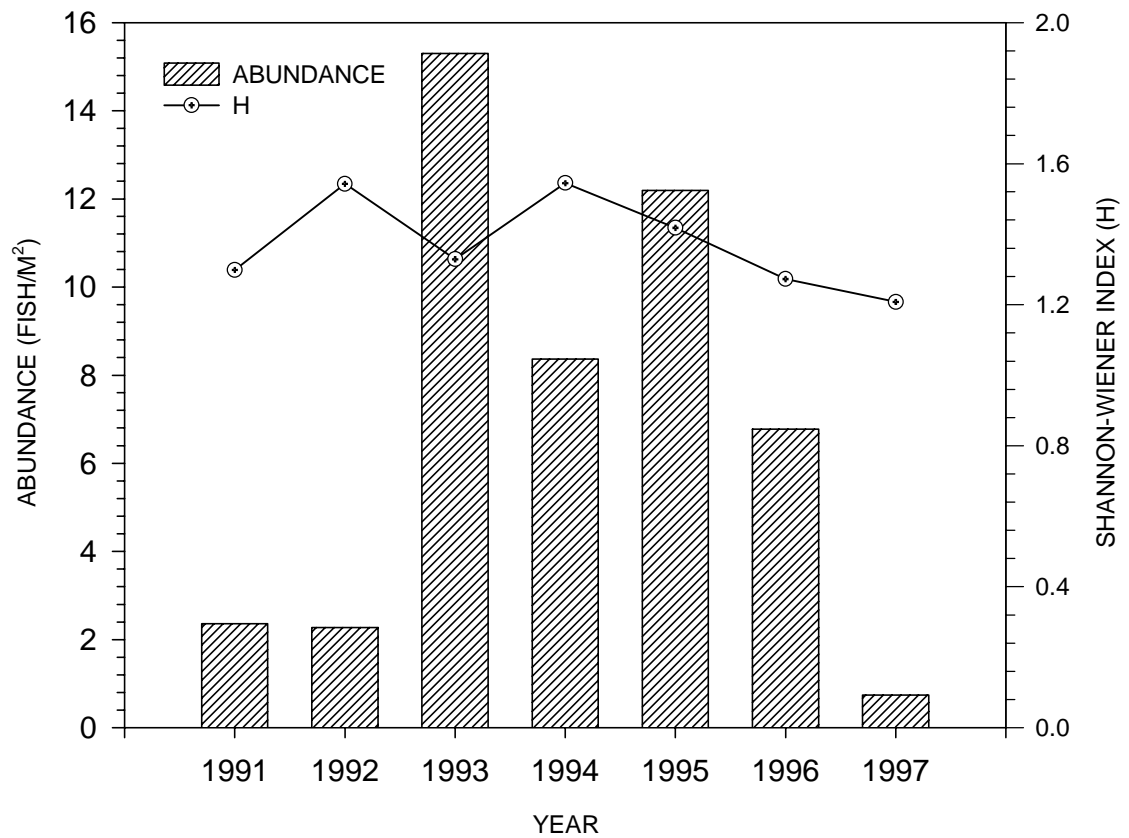
Figure 48. Abundance of fishes and Shannon-Wiener Diversity
Index values of fish assemblages in San Juan River
secondary channels (Geomorphic Reaches combined)
during summer, 1991 - 1997.

considerably (Table 17). Total abundance peaked in 1993 at 25.2 fish/m^2 and thereafter declined to the Reach low of 1.26 fish/m^2 in 1997. Although abundance varied considerably, little change was noted in Shannon-Wiener Diversity Index values (Figure 50). There was no correlation between discharge at time of sampling and total abundance ($r^2 = 0.141$, $p = 0.407$).

Table 17. Number and abundance (fish/m^2) of fishes in San Juan River secondary channels in Geomorphic Reach 5 (RM 154 – RM 131) during summer, 1991 – 1997. Bold-lettered species used to calculate Kendall's coefficient of concordance (W).

1991			1992			1993			1994		
SPECIES	N	ABUN	SPECIES	N	ABUN	SPECIES	N	ABUN	SPECIES	N	ABUN
CYPLUT	997	2.44	**CYPLUT**	316	1.32	**CYPLUT**	5448	11.16	**PIMPRO**	2387	5.14
PIMPRO	13	0.32	**CATLAT**	123	0.51	**PIMPRO**	3546	7.27	**RHIOSC**	1777	3.83
RHIOSC	103	0.25	**CATDIS**	88	0.37	**RHIOSC**	1765	3.62	**CYPLUT**	445	0.96
GAMAFF	77	0.19	**PIMPRO**	64	0.27	**CATDIS**	1159	2.38	**ICTPUN**	287	0.62
CATLAT	71	0.17	**RHIOSC**	61	0.25	**CATLAT**	234	0.48	**CATDIS**	151	0.33
CATDIS	31	0.08	**GAMAFF**	12	0.05	**GAMAFF**	104	0.21	**GAMAFF**	127	0.27
CYPCAR	7	0.02	**FUNZEB**	8	0.03	**ICTPUN**	29	0.06	**CATLAT**	83	0.18
FUNZEB	3	0.01	**ICTPUN**	2	0.01	**CYPCAR**	19	0.04	**CYPCAR**	75	0.16
MICSAL	3	0.01	LEPCYA	2	0.01	**MICSAL**	3	0.01	**FIMZEB**	8	0.02
LEPCYA	1	<0.01	**CYPCAR**	1	<0.01				**MICSAL**	1	<0.01
TOTAL N	1423			677			12307			5341	
AREA	408			340			488			464	
ABUND	3.488			2.821			25.219			11.511	

1995			1996			1997		
SPECIES	N	ABUN	SPECIES	N	ABUN	SPECIES	N	ABUN
CATDIS	1981	3.30	**PIMPRO**	1045	2.90	**CYPLUT**	359	0.50
CYPLUT	1209	2.02	**CYPLUT**	830	2.31	**RHIOSC**	316	0.44
RHIOSC	853	1.42	**GAMAFF**	586	1.63	**PIMPRO**	161	0.22
PIMPRO	436	0.73	**RHIOSC**	117	0.33	**GAMAFF**	43	0.06
GAMAFF	131	0.22	**CATLAT**	54	0.15	**CATLAT**	23	0.03
CATLAT	81	0.14	**CATDIS**	28	0.08	AMEMEL	3	<0.01
CYPCAR	8	0.01	**FUNZEB**	19	0.05	**CYPCAR**	2	<0.01
MICSAL	8	0.01	**ICTPUN**	10	0.03	**ICTPUN**	1	<0.01
LEPCYA	2	<0.01	AMEMEL	4	0.01			
			CYPCAR	3	0.01			
			LEPCYA	1	<0.01			
TOTAL N	4709			2697			908	
AREA	600			360			720	
ABUND	7.848			7.492			1.261	

Red shiner was the most abundant species in 1991, 1992, 1993, and 1997. Fathead minnow was most abundant in 1994 and 1996 and bluehead sucker was most

Figure 49. Abundance of fishes and Shannon-Wiener Diversity Index
values of fish assemblages in Geomorphic Reach 5 secondary
channels, San Juan River, 1991 - 1997.

abundant in 1995. Speckled dace varied from the second- to fifth-most common species and flannelmouth sucker varied from second- to seventh-most abundant. Common carp and channel catfish, both common during spring inventories, were rare in most years. Despite some variation in abundance rank, concordance of ranks among years was high (W = 0.7551, $p < 0.001$). Expressed as a proportion, red shiner represented 25 to 75 % of each year's collection in all years except 1994 (Figure 51). Relative abundance of speckled dace, usually the most common native species, varied from 4 (1996, a low flow year) to 35 % (1997, a high flow spring runoff year with high summer flows). In 1995, a high spring runoff year, bluehead sucker was 42 % of the collection.

No attribute of spring runoff was significantly related to summer abundance of red shiner (Table 18), fathead minnow (Table 19), speckled dace (Table 20), flannelmouth sucker (Table 21) or channel catfish (Table 23). Number of days spring runoff > 5000 cfs had the strongest relationship with red shiner, fathead minnow, speckled dace, and flannelmouth sucker (Figure 52). Summer abundance of bluehead sucker was significantly related to several attributes of spring runoff (Table 22); the strongest was with days discharge > 3000 cfs (Figure 52).

Table 18. Results of linear regression analysis of relationship between spring runoff attributes and summer secondary channel abundance of red shiner, *Cyprinella lutrensis*, in Geomorphic Reach 5, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	r^2	r	*p*
Runoff volume (ac.ft.)	0.1310	0.3619	0.42
Runoff mean (ac. ft)	0.1796	0.4238	0.34
Days discharge > 3000 cfs	0.2585	0.5085	0.24
Days discharge > 5000 cfs	0.3813	0.6175	0.14
Days discharge > 8000 cfs	0.0144	0.1202	0.78

Table 19. Results of linear regression analysis of relationship between spring runoff attributes and summer secondary channel abundance of fathead minnow, *Pimephales promelas*, in Geomorphic Reach 5, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	r^2	r	*p*
Runoff volume (ac.ft.)	0.0292	0.1710	0.71
Runoff mean (ac. ft)	0.0608	0.2466	0.59
Days discharge > 3000 cfs	0.1157	0.3402	0.46
Days discharge > 5000 cfs	0.2307	0.4803	0.28
Days discharge > 8000 cfs	0.0325	0.1803	0.70
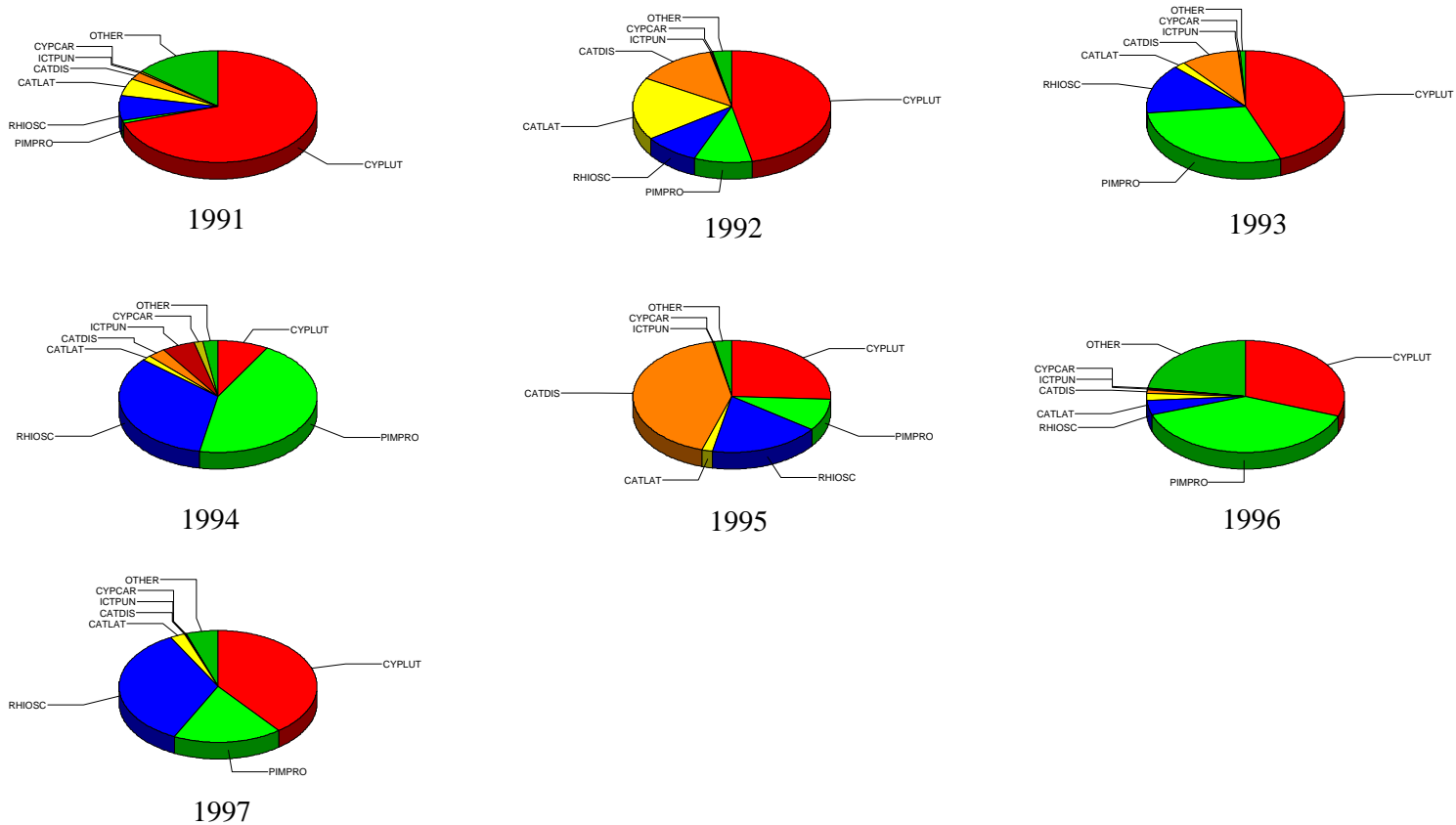
Figure 50. Relative abundance of commonly collected fishes in Geomorphic Reach 5, San Juan River, 1991 – 1997.

Table 20. Results of linear regression analysis of relationship between spring runoff attributes and summer abundance of speckled dace, *Rhinichthys osculus*, in Geomorphic Reach 5, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	r^2	r	*p*
Runoff volume (ac.ft.)	0.1475	0.3840	0.40
Runoff mean (ac. ft)	0.2094	0.4576	0.30
Days discharge > 3000 cfs	0.2808	0.5299	0.22
Days discharge > 5000 cfs	0.3991	0.6317	0.13
Days discharge > 8000 cfs	0.0103	0.1013	0.83

Table 21. Results of linear regression analysis of relationship between spring runoff attributes and summer abundance of flannelmouth sucker, *Catostomus latipinnis*, in Geomorphic Reach 5, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	r^2	r	*p*
Runoff volume (ac.ft.)	0.0742	0.2724	0.56
Runoff mean (ac. ft)	0.0843	0.2903	0.53
Days discharge > 3000 cfs	0.1673	0.4090	0.36
Days discharge > 5000 cfs	0.2093	0.4574	0.30
Days discharge > 8000 cfs	0.1220	0.3493	0.44

Table 22. Results of linear regression analysis of relationship between spring runoff attributes and summer abundance of bluehead sucker, *Catostomus discobolus*, in Geomorphic Reach 5, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	r^2	r	*p*
Runoff volume (ac.ft.)	0.6147*	0.7840	0.04
Runoff mean (ac. ft)	0.6175*	0.7858	0.04
Days discharge > 3000 cfs	0.6312*	0.7945	0.03
Days discharge > 5000 cfs	0.5923*	0.7696	0.04
Days discharge > 8000 cfs	0.3310	0.5759	0.18
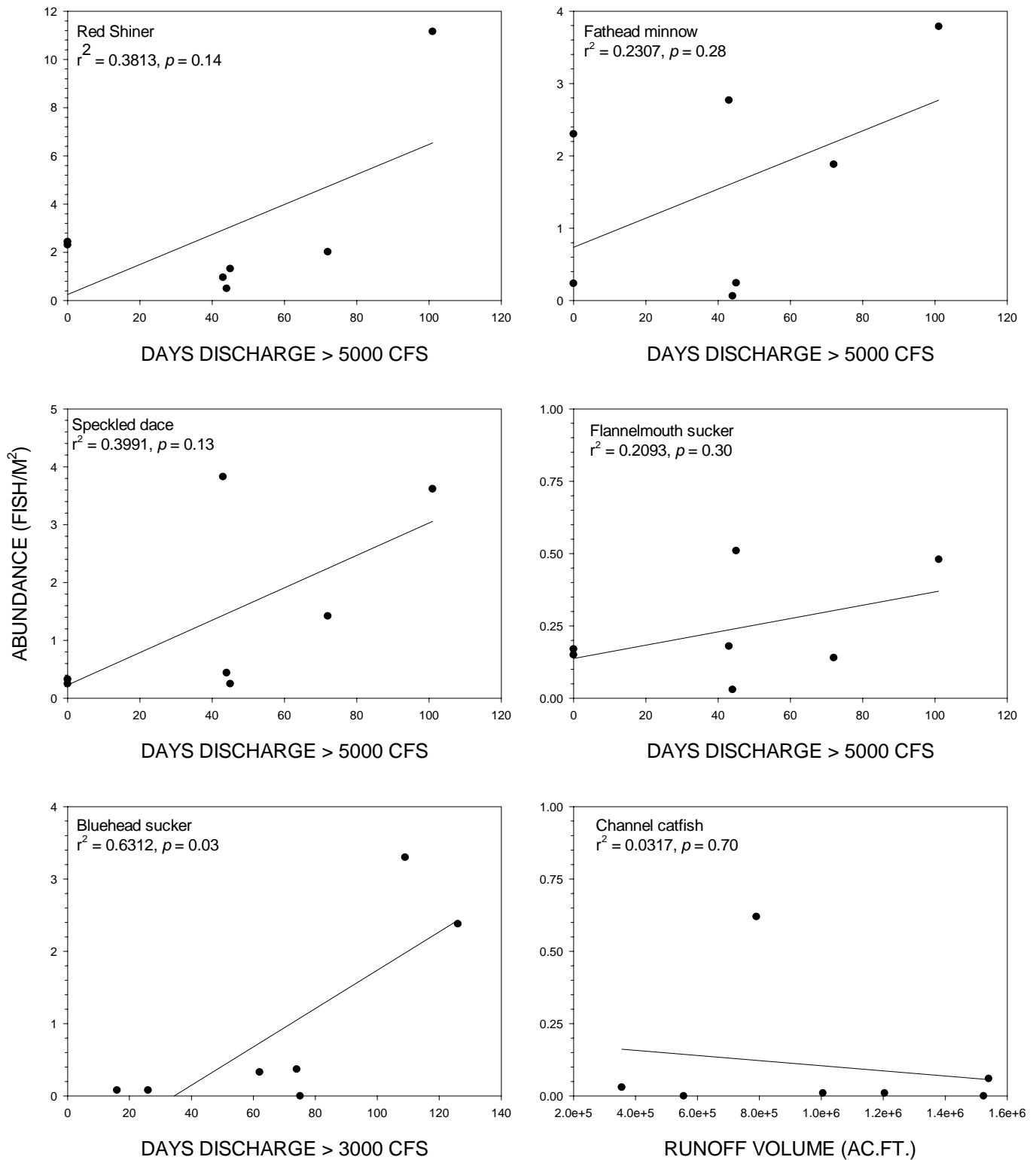
Figure 51. Secondary channel abundance of red shiner, fathead minnow, speckled dace, flannelmouth sucker, bluehead sucker, and channel catfish versus attributes of spring discharge, Geomorphic Reach 5, San Juan River, 1991 - 1997.

Table 23. Results of linear regression analysis of relationship between spring runoff attributes and summer abundance of channel catfish, *Ictalurus punctatus*, in Geomorphic Reach 5, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	r^2	r	*p*
Runoff volume (ac.ft.)	0.0317	0.1780	0.70
Runoff mean (ac. ft)	0.0125	0.1160	0.81
Days discharge > 3000 cfs	0.0028	0.0533	0.91
Days discharge > 5000 cfs	0.0013	0.0362	0.94
Days discharge > 8000 cfs	0.0238	0.1544	0.74

Geomorphic Reach 4

Twelve fish species, four native and eight nonnative, were collected in Geomorphic Reach 4 secondary channels between 1991 and 1997 (Table 24). Ten species were collected in each 1994 and 1996. Only three native species (speckled dace, flannelmouth sucker, and bluehead sucker) were regularly collected in Reach 4 secondary channels and roundtail chub was collected in 1997. Red shiner was the most abundant species in all years except 1996, when fathead minnow was most common. Speckled dace was always the second-most common species, except in 1994 and 1996 when it was third- and sixth-most common. Abundance rank of flannelmouth and bluehead suckers varied from year to year and bluehead sucker was absent from Reach 4 collections in 1992. Despite variation, overall abundance rank of species was fairly similar among years (W = 0.767, *p* < 0.001). Red shiner was at least 42 % of each summer collection, except 1997 (Figure 53). In 1996, nonnative fishes represented over 95 % of the collection.

Abundance of fishes in Reach 4 secondary channels peaked at about 17 fish/m^2 in 1993 and 1995, years of high spring runoff and moderately high summer flows. Abundance of fishes was lowest in 1991 (0.83/m^2) and 1997 (0.44/m^2). There was no relationship between discharge at time of sampling and abundance of fishes (r^2 = 0.058, *p* = 0.72). Assemblage diversity generally declined from 1991 through 1997 (Figure 54). In 1991, 1992, and 1994, years of comparatively high H values, the two most-abundant species represented about 70 % of the specimens. In years of comparatively low H values (1995, 1996, and 1997), the two most abundant species were 84 to 91 % of the collections.

The relationship between spring runoff attributes and species abundance was fairly strong for several attributes in Reach 4. Abundance of red shiner was positively related to all attributes of spring runoff and significantly related to days discharge > 5,000 cfs (Table 25 and Figure 55). Speckled dace abundance was significantly related to all spring runoff attributes except days discharge > 8,000 cfs (Table 26) and most strongly with days discharge > 5,000 cfs (Figure 55). The abundance of flannelmouth sucker and
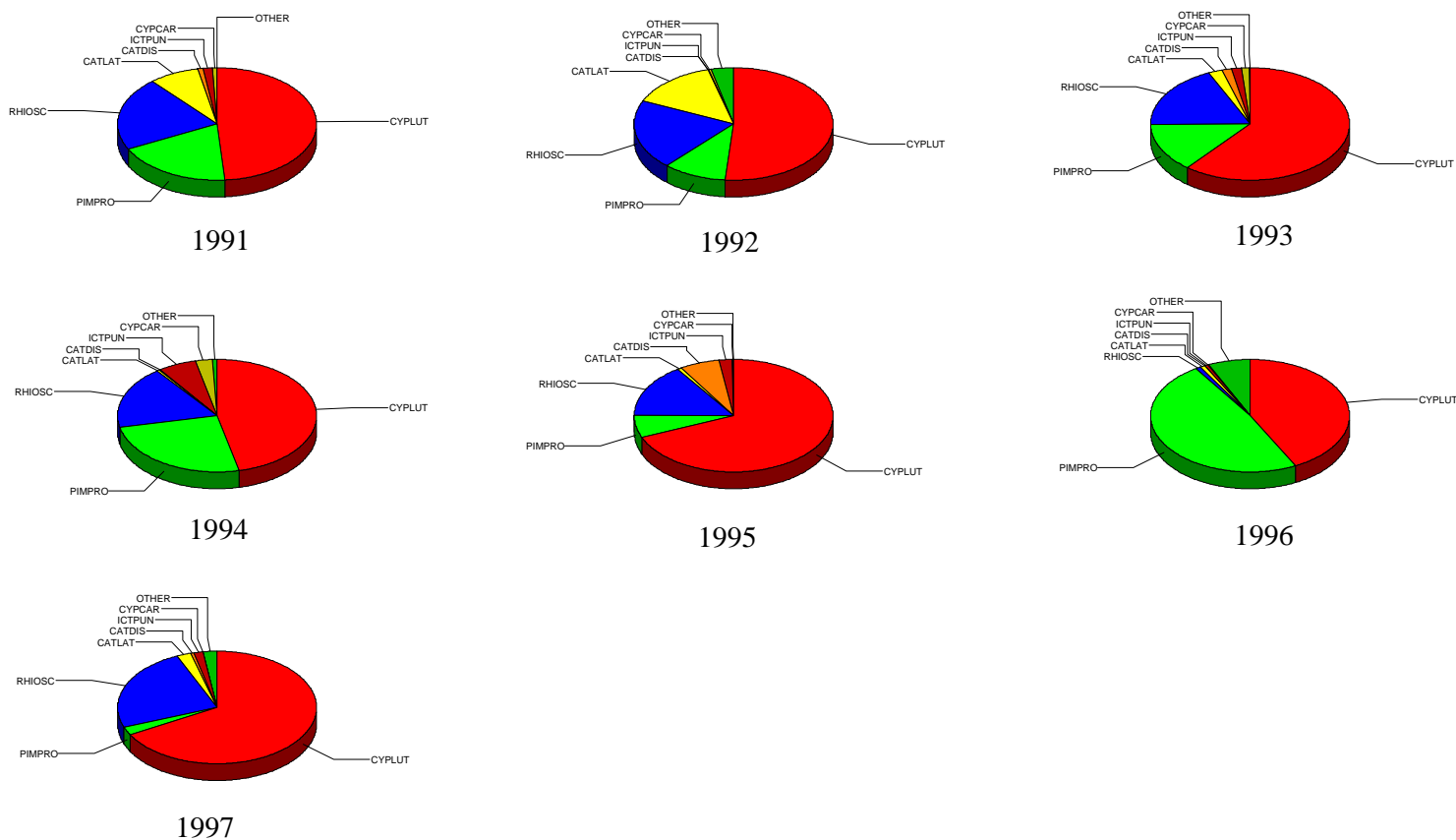
Figure 52. Relative abundance of commonly collected fishes in Geomorphic Reach 4
during summer, San Juan River, 1991 – 1997.

Table 24. Number and abundance (fish/m^2) of fishes in San Juan River secondary channels in Geomorphic Reach 4 (RM 130 – RM 106) during summer, 1991 – 1997. Bold-lettered species were used to calculate Kendall's coefficient of concordance (W).

	1991			1992			1993			1994		
SPECIES	N	ABUN	SPECIES	N	ABUN	SPECIES	N	ABUN	SPECIES	N	ABUN
CYPLUT	65	0.41	**CYPLUT**	358	1.32	**CYPLUT**	6969	10.62	**CYPLUT**	2212	4.01
RHIOSC	28	0.18	**RHIOSC**	139	0.51	**RHIOSC**	2099	3.20	**PIMPRO**	1206	2.18
PIMPRO	25	0.16	**CATLAT**	98	0.36	**PIMPRO**	1600	2.44	**RHIOSC**	854	1.55
CATLAT	11	0.07	**PIMPRO**	72	0.26	**CATLAT**	262	0.40	**ICTPUN**	289	0.52
ICTPUN	2	0.01	**GAMAFF**	23	0.08	**CATDIS**	182	0.28	**CYPCAR**	134	0.24
CATDIS	1	0.01	**CYPCAR**	3	0.01	**ICTPUN**	177	0.27	**GAMAFF**	28	0.05
CYPCAR	1	0.01	**FUNZEB**	2	0.01	**CYPCAR**	147	0.22	**CATLAT**	25	0.05
			ICTPUN	1	<0.01	**GAMAFF**	9	0.01	**CATDIS**	9	0.02
									FUNZEB	8	0.01
									MICSAL	1	<0.01

	1991		1992		1993		1994	
TOTAL N	133		696		11445		4766	
AREA	160		272		656		552	
ABUN	0.831		2.559		17.447		8.634	

	1995			1996			1997		
SPECIES	N	ABUN	SPECIES	N	ABUN	SPECIES	N	ABUN
CYPLUT	10642	11.88	**PIMPRO**	2068	3.98	**CYPLUT**	40	0.29
RHIOSC	2362	2.64	**CYPLUT**	1809	3.48	**RHIOSC**	147	0.11
CATDIS	993	1.11	AMEMEL	188	0.36	**CATLAT**	14	0.01
PIMPRO	993	1.11	**GAMAFF**	107	0.21	**PIMPRO**	14	0.01
ICTPUN	346	0.39	**CATLAT**	35	0.07	GILROB	9	0.01
CATLAT	119	0.13	**RHIOSC**	33	0.06	**ICTPUN**	9	0.01
GAMAFF	22	0.02	**ICTPUN**	26	0.05	**GAMAFF**	6	<0.01
CYPCAR	3	<0.01	**CYPCAR**	2	<0.01	AMEMEL	5	<0.01
MICSAL	2	<0.01	**MICSAL**	2	<0.01	**CATDIS**	3	<0.01
			FUNZEB	1	<0.01			

	1995		1996		1997	
TOTAL N	15482		4271		607	
AREA	896		520		1371	
ABUN	17.279		8.214		0.443	

bluehead sucker was not significantly related to any flow attribute (Tables 27 and 28), but was moderately strong for days discharge > 5,000 cfs (flannelmouth sucker, Figure 55) and days discharge > 8,000 cfs (bluehead sucker, Figure 55). Summer abundance of fathead minnow and channel catfish in Reach 4 did not appear to be related to spring runoff attributes (Tables 29 and 30, Figure 55).
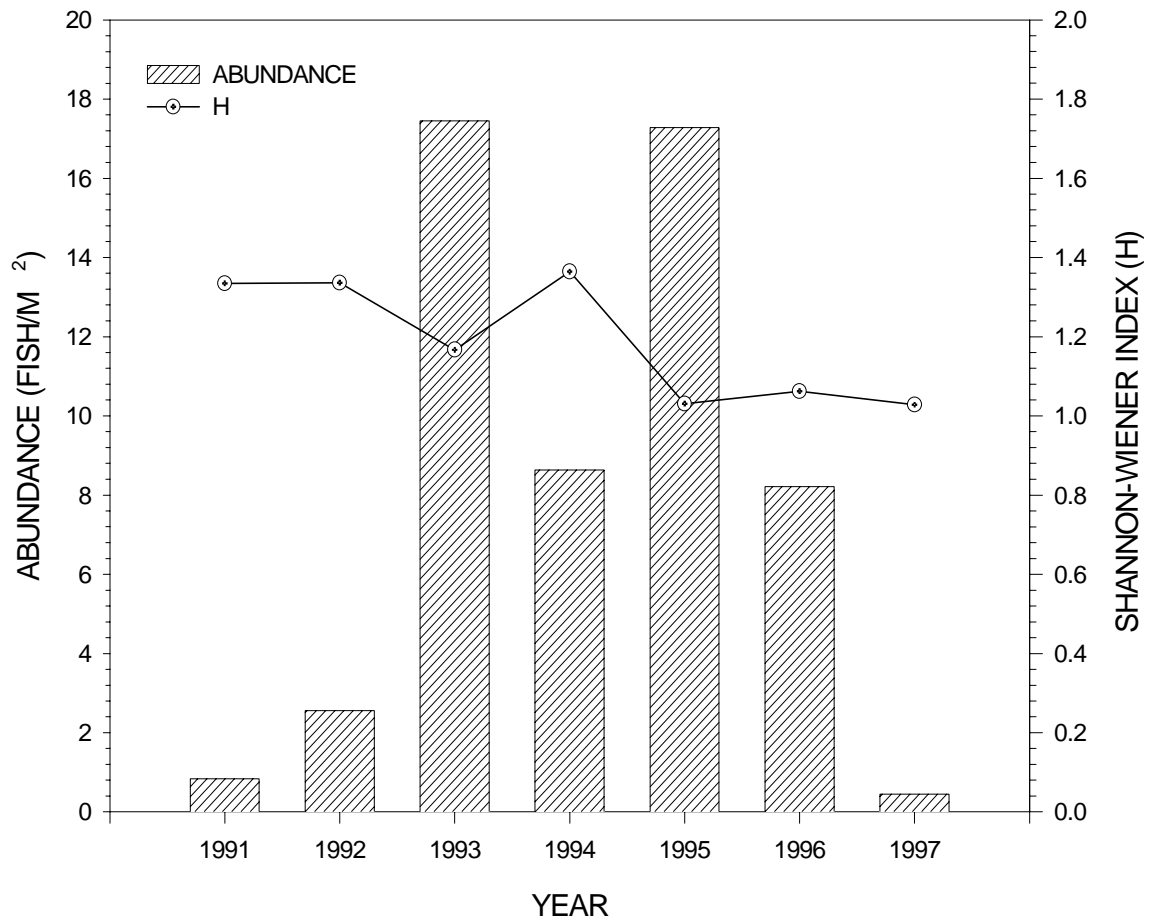
Figure 53. Abundance of fishes and Shannon-Wiener Diversity Index
values of fish assemblages in Geomorphic Reach 4 secondary
channels, San Juan River, 1991 - 1997.

Figure 54. Secondary channel abundance of red shiner, speckled dace, bluehead sucker, fathead minnow, flannelmouth sucker, and channel catfish versus spring discharge attributes, Geomorphic Reach 4, San Juan River, 1991 - 1997.

90

Table 25. Results of linear regression analysis of relationship between spring runoff attributes and summer secondary channel abundance of red shiner, *Cyprinella lutrensis*, in Geomorphic Reach 4, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	r^2	r	*p*
Runoff volume (ac.ft.)	0.4528	.6729	0.10
Runoff mean (ac.ft.)	0.4822	.6944	0.08
Days discharge > 3000 cfs	0.5227	.7264	0.06
Days discharge > 5000 cfs	0.5557	.7454	0.05
Days discharge > 8000 cfs	0.2065	.4545	0.31

Table 26. Results of linear regression analysis of relationship between spring runoff attributes and summer secondary channel abundance of fathead minnow, *Pimephales promelas*, in Geomorphic Reach 4, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	r^2	r	*p*
Runoff volume (ac.ft.)	0.0800	0.2821	0.54
Runoff mean (ac.ft.)	0.0540	0.2324	0.62
Days discharge > 3000 cfs	0.0243	0.1559	0.74
Days discharge > 5000 cfs	0.0009	0.0297	0.95
Days discharge > 8000 cfs	0.1091	0.3303	0.47

Table 27. Results of linear regression analysis of relationship between spring runoff attributes and summer secondary channel abundance of speckled dace, *Rhinichthys osculus*, in Geomorphic Reach 4, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	r^2	r	*p*
Runoff volume (ac.ft.)	0.5753*	0.7585	0.05
Runoff mean (ac.ft.)	0.6311*	0.7944	0.03
Days discharge > 3000 cfs	0.7085*	0.8417	0.02
Days discharge > 5000 cfs	0.7645*	0.8423	0.01
Days discharge > 8000 cfs	0.1739	0.4170	0.35

Table 28. Results of linear regression analysis of relationship between spring runoff attributes and summer secondary channel abundance of flannelmouth sucker, *Catostomus latipinnis*, in Geomorphic Reach 4, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	r^2	r	*p*
Runoff volume (ac.ft.)	0.2857	0.5345	0.22
Runoff mean (ac.ft.)	0.3259	0.5708	0.18
Days discharge > 3000 cfs	0.3851	0.6206	0.14
Days discharge > 5000 cfs	0.4554	0.6868	0.09
Days discharge > 8000 cfs	0.0095	0.0976	0.84

Table 29. Results of linear regression analysis of relationship between spring runoff attributes and summer secondary channel abundance of bluehead sucker, *Catostomus discobolus*, in Geomorphic Reach 4, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	r^2	r	*p*
Runoff volume (ac.ft.)	0.4153	0.6444	0.12
Runoff mean (ac.ft.)	0.3913	0.6256	0.13
Days discharge > 3000 cfs	0.3533	0.5944	0.16
Days discharge > 5000 cfs	0.2765	0.5258	0.23
Days discharge > 8000 cfs	0.4611	0.6791	0.09

Table 30. Results of linear regression analysis of relationship between spring runoff attributes and summer secondary channel abundance of channel catfish, *Ictalurus punctatus*, in Geomorphic Reach 4, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	r^2	r	*p*
Runoff volume (ac.ft.)	0.1686	0.4106	0.36
Runoff mean (ac.af.)	0.1450	0.3808	0.40
Days discharge > 3000 cfs	0.2113	0.4157	0.30
Days discharge > 5000 cfs	0.2618	0.5116	0.24
Days discharge > 8000 cfs	0.0925	0.3041	0.51

Geomorphic Reach 3

Between 1991 and 1997, 13 species of fish were captured in Reach 3 (Table 31). Red shiner was the most abundant species in all years, except 1995 and 1996 when fathead minnow was the most abundant. Speckled dace was the second-most abundant species in 1991 through 1993, 1995, and 1997. In 1994 and 1996, comparatively low flow years, it was third- and fourth-most abundant. Flannelmouth sucker was never particularly abundant, but was found each year. Bluehead sucker abundance was low (< $0.05/m^2$) or it was absent (1992 and 1996) in all years except 1993 and 1995. In the latter years, high spring runoff years, its abundance was comparatively high (> $0.3/m^2$). Roundtail chub and Colorado pikeminnow were collected in 1997. The abundance rank of species was similar among years (W = 0.749, *p* < 0.001). Relative abundance of speckled dace varied from less than 5 % (1996, a low flow year) to more than 30 % of the collection (1993 and 1995, high spring runoff years; Figure 56). Fathead minnow was a comparatively large percent (> 10 %) of the collection in all years, except 1997. Red shiner was the largest proportion of the collection in all years, except 1995 and 1996, when fathead minnow was most common.

Overall abundance of fishes in Reach 3 secondary channels peaked in 1993 and 1995 (Figure 57). Between 1991 and 1997, Shannon-Wiener Diversity Index values generally declined (Figure 57). From 1991 through 1995, the two most-abundant species

1991

1992

1993

1994

1995

1996
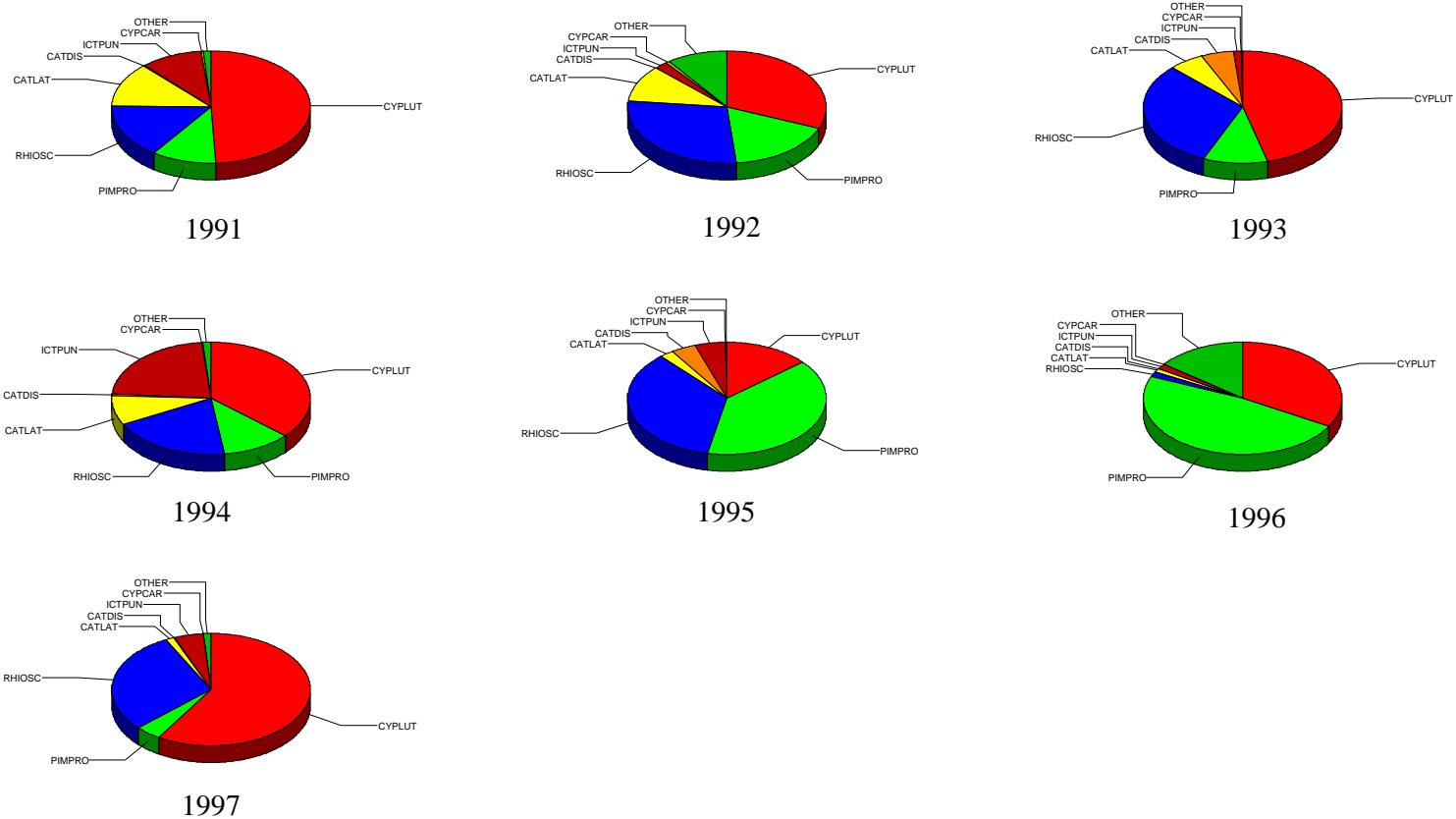
1997

Figure 55. Relative abundance of commonly collected fishes in Geomorphic Reach 3 secondary channels, San Juan River, 1991 – 1997.
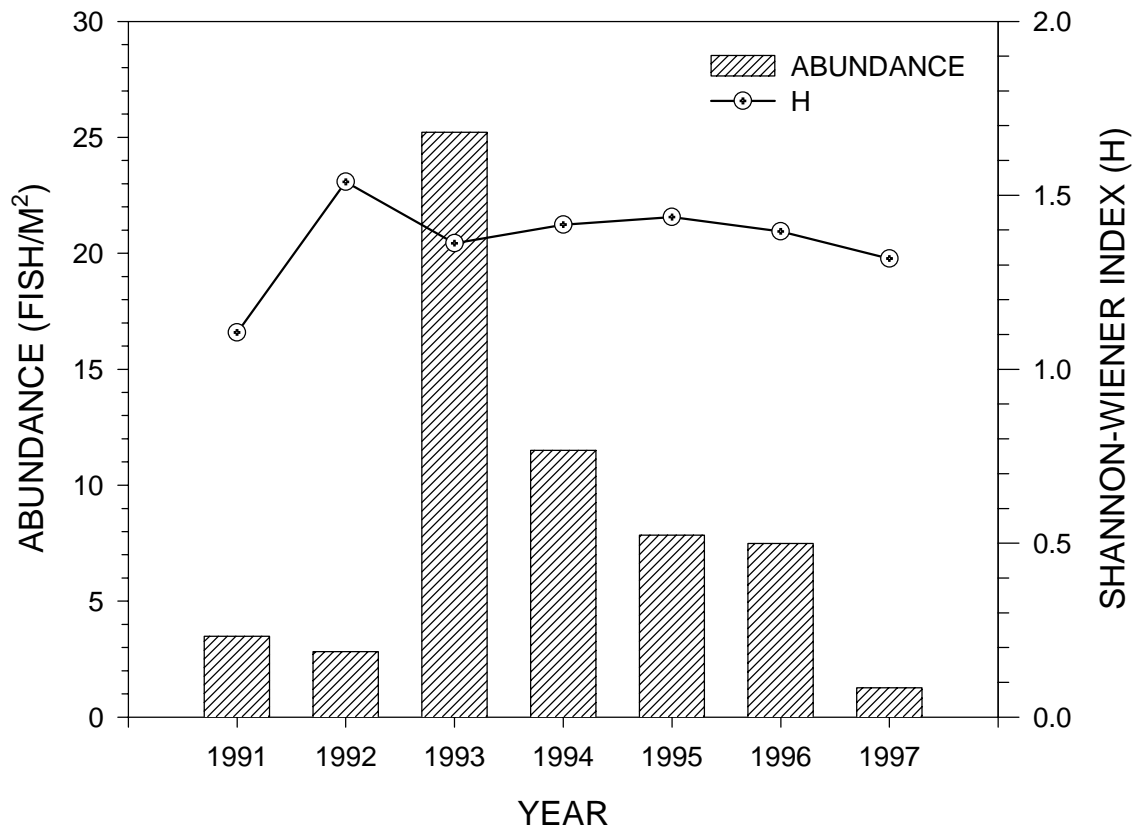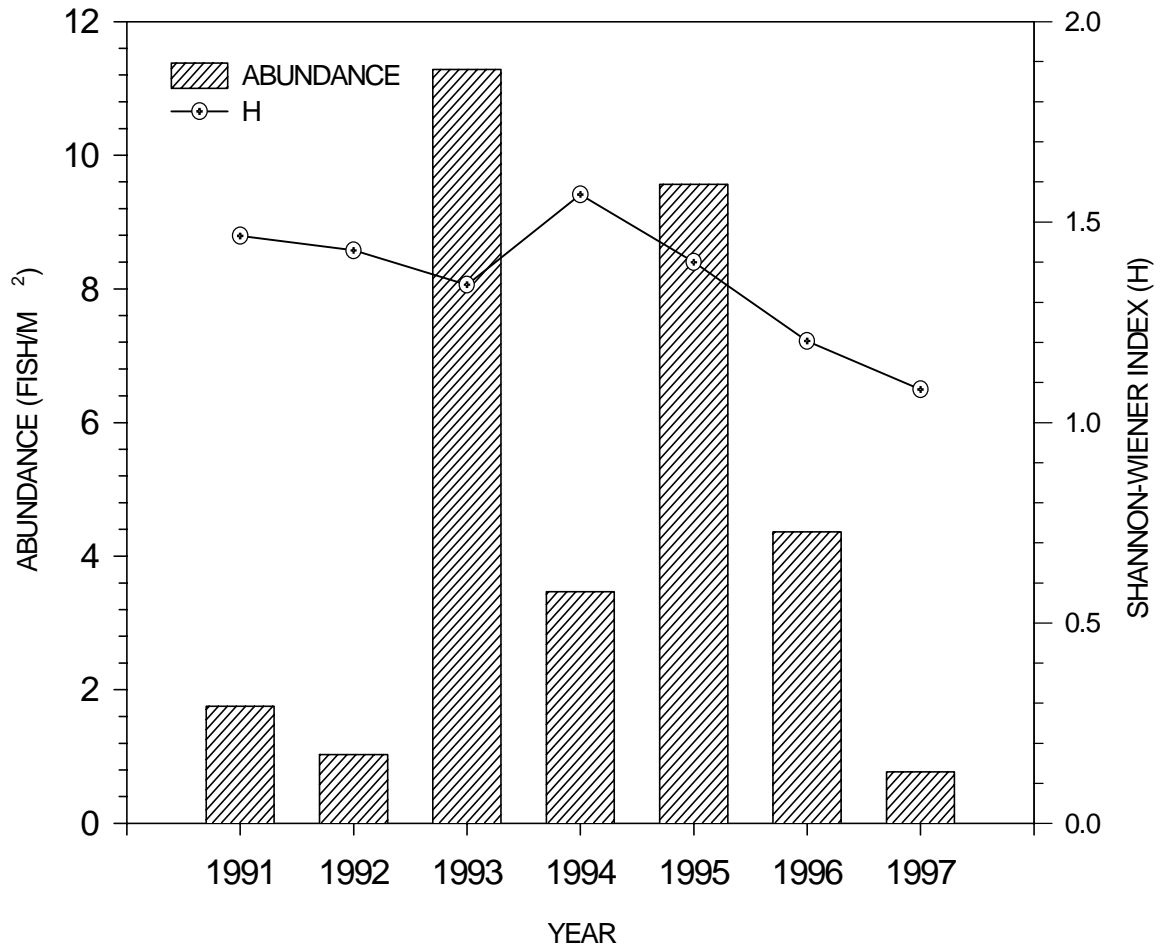
Figure 56. Abundance of fishes and Shannon-Wiener Diversity
            Index values of fish assemblages in Geomorphic Reach 3
            secondary channels, San Juan River, 1991 - 1997.

Table 31. Number and abundance (fish/m^2) of fishes in San Juan River secondary channels in Geomorphic Reach 3 (RM 105 – RM 68) during summer, 1991 – 1997. Bold-lettered species were used to calculate Kendall's coefficient of concordance (W).

1991			1992			1993			1994		
SPECIES	N	ABUN	SPECIES	N	ABUN	SPECIES	N	ABUN	SPECIES	N	ABUN
CYPLUT	311	0.86	CYPLUT	54	0.32	CYPLUT	1617	5.18	CYPLUT	416	1.27
RHIOSC	97	0.27	**RHIOSC**	49	0.29	**RHIOSC**	1093	3.50	ICTPUN	254	0.77
CATLAT	81	0.23	**PIMPRO**	30	0.18	**PIMPRO**	370	1.19	RHIOSC	221	0.67
PIMPRO	66	0.18	**CATLAT**	18	0.11	**CATLAT**	205	0.66	**PIMPRO**	128	0.39
ICTPUN	64	0.18	**GAMAFF**	12	0.07	**CATDIS**	188	0.60	**CATLAT**	95	0.29
GAMAFF	7	0.02	**FUNZEB**	5	0.03	**ICTPUN**	42	0.13	**GAMAFF**	16	0.05
CATDIS	2	0.01	**ICTPUN**	4	0.02	**CYPCAR**	4	0.01	**CATDIS**	6	0.02
CYPCAR	2	0.01	**CYPCAR**	1	0.01	**GAMAFF**	2	0.01	**CYPCAR**	1	<0.01
LEPCYA	1	<0.01									
TOTAL N	631			173			3521			1137	
AREA	360			168			312			328	
ABUN	1.753			1.030			11.285			3.467	

1995			1996			1997		
SPECIES	N	ABUN	SPECOES	N	ABUN	SPECIES	N	ABUN
PIMPRO	2789	3.75	PIMPRO	872	2.10	CYPLUT	576	0.46
RHIOSC	2510	3.37	**CYPLUT**	604	1.45	**RHIOSC**	288	0.23
CYPLUT	990	1.33	**GAMAFF**	253	0.61	**ICTPUN**	47	0.04
ICTPUN	346	0.47	**RHIOSC**	28	0.07	**PIMPRO**	40	0.03
CATDIS	288	0.39	**ICTPUN**	27	0.06	**CATLAT**	13	0.01
CATLAT	166	0.22	**CATLAT**	19	0.05	**GAMAFF**	7	0.01
GAMAFF	15	0.02	**FUNZEB**	11	0.03	GILROB	5	<0.01
CYPCAR	7	0.01	**MICSAL**	1	<0.01	CATDIS	1	<0.01
FUNZEB	6	0.01				PYTLUC	1	<0.01
MICSAL	1	<0.01						
TOTAL N	7118			1815			978	
AREA	744			416			1264	
ABUN	9.567			4.363			0.774	

represented 59 to 74 % of the collection, but in 1996 and 1997 the two-most abundant species accounted for > 80 % of the collection. There was no relationship between fish abundance and discharge at time of sampling ($r^2 = 0.039$, $p = 0.67$).

Attributes of spring runoff were significantly related to the abundance of three species commonly collected in Reach 3. Red shiner abundance was significantly related to days discharge > 5,000 cfs (Table 32, Figure 58). Four of five spring runoff attributes were related to speckled dace and bluehead sucker abundance (Tables 34 and 36, Figure 58); only days discharge > 8,000 cfs was not related to their abundance. Abundance of flannelmouth sucker was positively related to all attributes of spring runoff, except days discharge > 8,000 cfs (no relationship), but none was significant (Table 35, Figure 58).

There was no relationship between any spring runoff attribute and abundance of fathead minnow and channel catfish (Tables 33 and 37, Figure 58).

Table 32. Results of linear regression analysis of relationship between attributes of spring runoff and summer secondary channel abundance of red shiner, *Cyprinella lutrensis*, in Geomorphic Reach 3, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	R^2	R	P
Runoff volume (ac.ft.)	0.4227	0.6540	0.11
Runoff mean (cfs)	0.4646	0.6816	0.09
Days discharge > 3000 cfs	0.5129	0.7162	0.07
Days discharge > 5000 cfs	0.5697*	0.7548	0.05
Days discharge > 8000 cfs	0.1119	0.3345	0.46

*significant relationship ($P \leq 0.05$)

Table 33. Results of linear regression analysis of relationship between attributes of spring runoff and summer secondary channel abundance of fathead minnow, *Pimephales promelas*, in Geomorphic Reach 3, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	R^2	R	P
Runoff volume (ac.ft.)	0.0886	0.2976	0.52
Runoff mean (cfs)	0.0816	0.2857	0.54
Days runoff > 3000 cfs	0.767	0.2769	0.55
Days runoff > 5000 cfs	0.0637	0.2523	0.59
Days runoff > 8000 cfs	0.1646	0.4057	0.37

Table 34. Results of linear regression analysis of relationship between attributes of spring runoff and summer secondary channel abundance of speckled dace, *Rhinichthys osculus*, in Geomorphic Reach 3, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	R^2	R	P
Runoff volume (ac.ft.)	0.6556*	0.8097	0.03
Runoff mean (cfs)	0.6799*	0.8246	0.02
Days runoff > 3000 cfs	0.7095*	0.8423	0.02
Days runoff > 5000 cfs	0.7095*	0.8423	0.02
Days runoff > 8000 cfs	0.2739	0.5234	0.23

*significant relationship ($P \leq 0.05$)

Table 35. Results of linear regression analysis of relationship between spring runoff attributes and summer secondary channel abundance of flannelmouth sucker, *Catostomus latipinnis*, in Geomorphic Reach 3, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	R^2	R	P
Runoff volume (ac.ft.)	0.2263	0.4757	0.28
Runoff mean (cfs)	0.2772	0.5265	0.23
Days discharge > 3000 cfs	0.3603	0.6002	0.15
Days discharge > 5000 cfs	0.4554	0.6749	0.10
Days discharge > 8000 cfs	0.0010	0.0322	0.95

Table 36. Results of linear regression analysis of relationship between spring runoff attributes and summer secondary channel abundance of bluehead sucker, *Catostomus discobolus*, in Geomorphic Reach 3, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	R^2	R	P
Runoff volume (ac.ft.)	0.6050*	0.7778	0.04
Runoff mean (cfs)	0.6360*	0.7975	0.03
Days discharge > 3000 cfs	0.6790*	0.8240	0.02
Days discharge > 5000 cfs	0.7125*	0.8441	0.02
Days discharge > 8000 cfs	0.1738	0.4169	0.35

*significant relationship (P ≤ 0.05)

Table 37. Results of linear regression analysis of relationship between spring runoff attributes and summer secondary channel abundance of channel catfish, *Ictalurus punctatus*, in Geomorphic Reach 3, San Juan River, 1991 – 1997.

RUNOFF ATTRIBUTE	R^2	R	P
Runoff volume (ac.ft.)	0.0044	0.0661	0.89
Runoff mean (cfs)	0.124	0.1113	0.81
Days discharge > 3000 cfs	0.0181	0.1346	0.77
Days discharge > 5000 cfs	0.0268	0.1636	0.73
Days discharge > 8000 cfs	0.0286	0.1692	0.72

Inter-Reach Comparisons

Over the course of the study, Shannon-Wiener Diversity Index values were generally higher in Reach 5 than downstream reaches and lowest in Reach 4 (Figure 59). The exceptions were 1993 when assemblage diversity was lowest in Reach 5 and 1994 when it was highest in Reach 3. Averaged over the years of study, assemblage diversity was higher in Reach 5 (H = 1.3619, CV = 10.0 %) than Reach 3 (H = 1.3561, CV = 12.2 %). Mean assemblage diversity was 1.1891 (CV = 15.3 %) in Reach 4. Diversity,
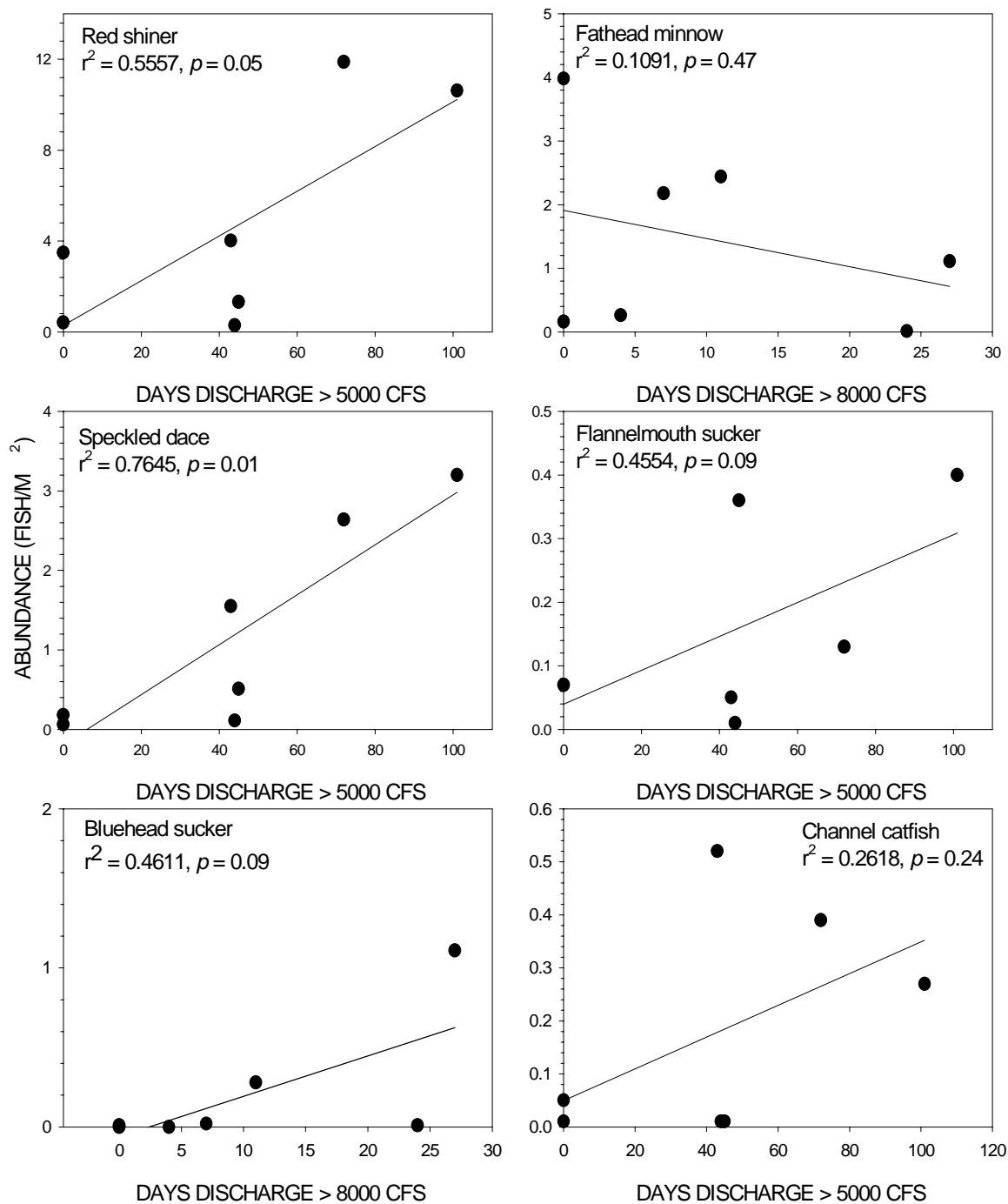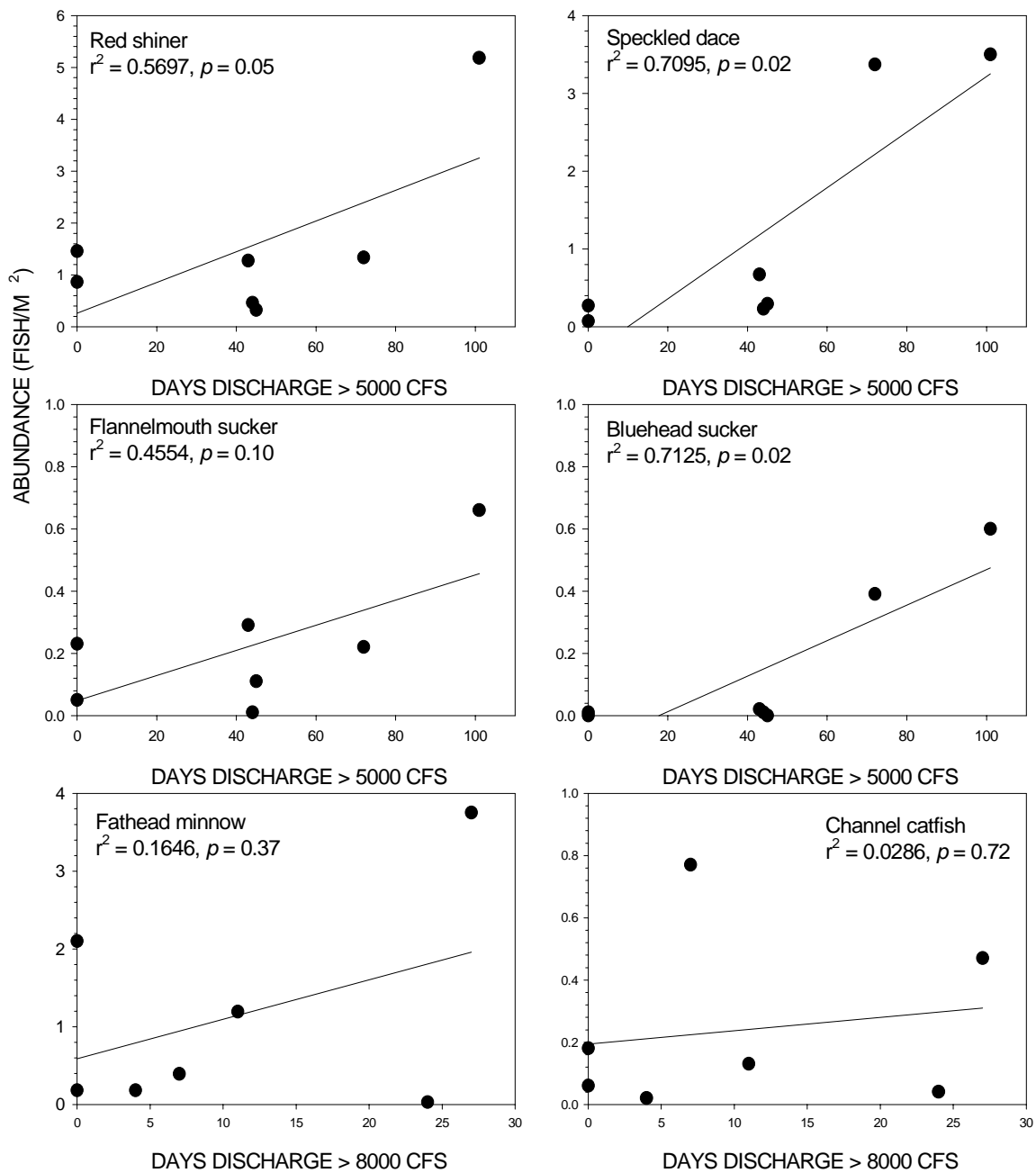
Figure 57. Secondary channel abundance of red shiner, speckled dace, flannelmouth sucker, bluehead sucker, fathead minnow, and channel catfish versus attributes of spring discharge, Geomorphic Reach 3, San Juan River, 1991 - 1997.

however, was not significantly different among years (F = 1.488, p = 0.25) or among reaches (F = 2.068, p = 0.16).

Fish abundance varied considerably among reaches within years and particularly among years within reaches (Figure 59). It was low (< 5 fish/m^2) in 1991, 1992, and 1997, high (> 10 fish/m^2) in all reaches in 1993, and intermediate (> 5 and < 10 fish/m^2) in most reaches in 1994 through 1996. From 1991 through 1994 and in 1997, total abundance was highest in Reach 5. In 1995 and 1996, total abundance was greatest in Reach 4. Total abundance was lowest in Reach 3 in all years except 1991 and 1997. Among reach differences in abundance were not significant (F = 1.004, p = 0.39), but among year differences were (F = 8.199, p = 0.0006). Post-hoc tests indicated that abundance in 1993 was significantly greater than all years except 1994 and 1995 and that abundance in 1995 was greater than in 1997.

Five secondary channels were sampled in 6 of 7 or 7 of 7 years. The most upstream was at RM 144.0 to RM 143.8 and the most downstream was at RM 94.3 to RM 94.0. Two were in Reach 5, two in Reach 4, and one in Reach 3. Abundance varied considerably from year to year in each secondary channel (Figure 60). In the three most-upstream secondary channels, greatest abundance was in 1993. Highest abundance in the most-downstream secondary channel was in 1995. There was no consistent pattern in changes in assemblage diversity, it generally declined over time in three and was about the same in two in 1991 or 1992 and 1997. Neither within-years nor within-secondary channel differences were significant (F = 2.286, p 0.07 and F = 0.938, p = 0.49). Although there was a large amount of variation in the abundance of each species across years, rank abundance remained fairly constant. There was moderately high to high concordance of abundance rank across years within each secondary channel except the RM 144.0 to RM 143.8 secondary channel. There, Kendall's W was 0.291 (p < 0.106); Kendall's W for all others was $\geq$ 0.48 (p <0.008). Despite variation in abundance, neither within-years nor within-secondary channel differences were significant (F = 1.643, p = 0.19 and F = 0.854, p = 0.50). In the secondary channel (RM 144.0 to RM 143.8) where abundance rank changed considerably from year to year, red shiner was the most abundant species in only one year (1996) of six years. Native speckled dace and bluehead sucker were each the most abundant in two years (1991 and 1997; 1993 and 1995). In the sixth year (1994), channel catfish was the most abundant species. In each of the other commonly sampled, and downstream, secondary channels red shiner was the most abundant species in most years. Speckled dace was the most abundant species in RM 132.2 to RM 131.05 (1994) and RM 116.55 to RM 115.6 (1994). Fathead minnow was the most abundant species in RM 122.8 to RM 122.05 in 1993 and 1994 and in RM 94.3 to RM 94.0 in 1994.
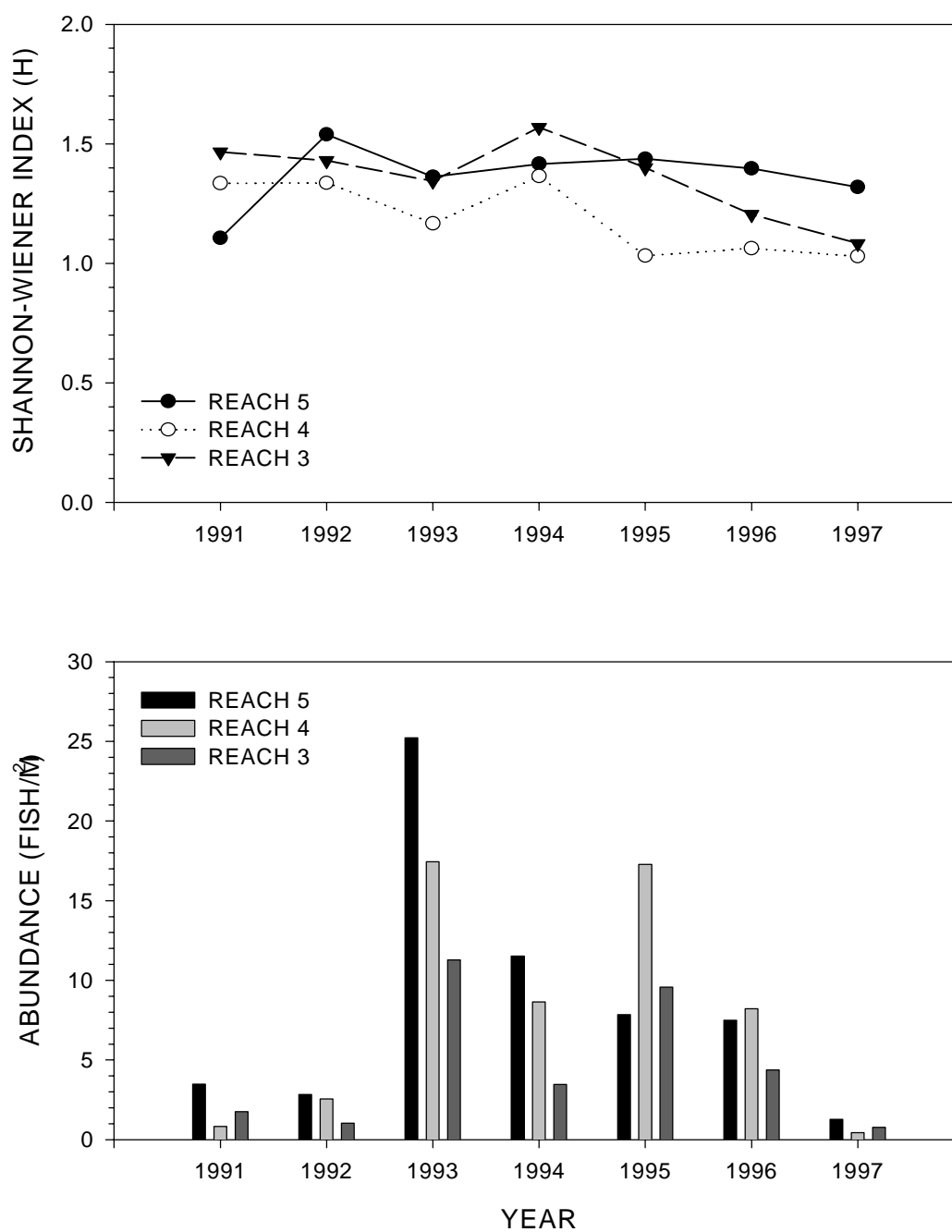
Figure 58. Shannon-Wiener Diversity Index values of fish assemblages and abundance of fishes in San Juan River secondary channels during summer, 1991 - 1997.
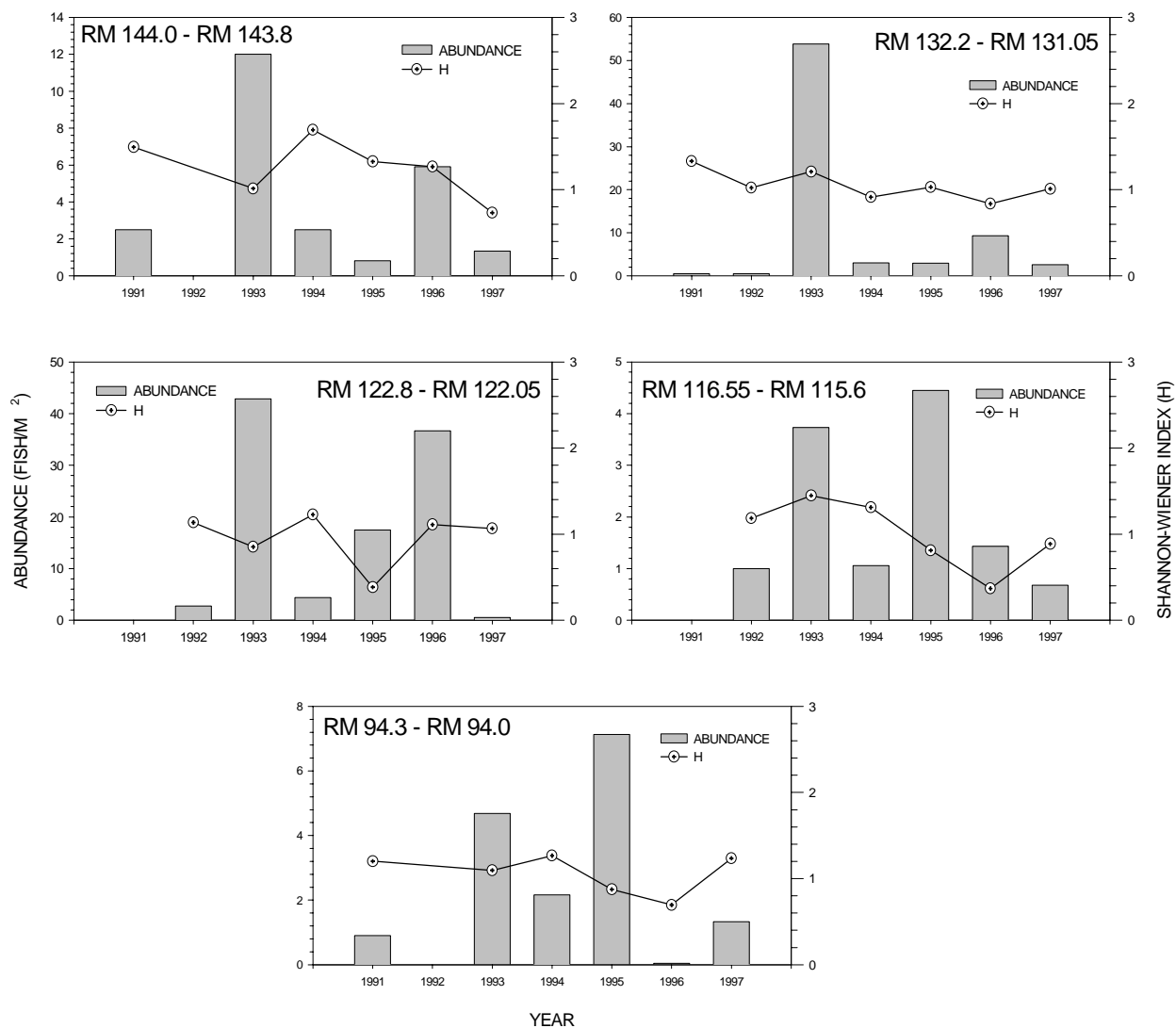
Figure 59. Abundance of fishes and Shannon-Wiener Diversity Index values
of secondary channel fish assemblages for commonly sampled
San Juan River secondary channels during summer, 1991 - 1997.

FISH ASSEMBLAGES OF SAN JUAN RIVER

SECONDARY CHANNELS DURING AUTUMN

1993 - 1997

INTRODUCTION

Autumn inventories of San Juan River secondary channels were initiated in 1993 to enable a more accurate and complete characterization of the fish assemblages of secondary channels and dynamics of species populations within these habitats than could be obtained from only spring and summer inventories. Overall objectives of the Secondary Channel Ichthyofaunal Inventory were:

1)   Characterize the type of secondary channels in the San Juan River;
2)   Characterize the faunal assemblages of secondary channels;
3)   Determine seasons use patterns of secondary channels by target species; and
4)   Relate habitat use and availability of secondary channels to flow levels.

Specifically, autumn inventories provided data necessary to meet and complete study objectives 2, 3, and 4.

METHODS

The study area was the San Juan River from Shiprock (RM 147.9) to Chinle Creek (RM 68.7), except 1993 when sampling was terminated at Sand Island (RM 76.5). See Study Area description in preceding chapter for detailed description of study area.

Sampling methods during autumn inventories were the same as used during summer inventories. Autumn inventories were initiated in 1993 and continued through 1997. Sampling was done during the first two weeks of October in all years, except 1996 when sampling occurred during the second and third week of October.

Kendall's coefficient of concordance (W) was used to evaluate changes in the abundance rank of fish species during autumn. Regression analysis was used to relate attributes of summer discharge (Table 38) to autumn abundance (fish/m^2) of each commonly collected fish species. The Shannon-Wiener Diversity Index (where H = $\Sigma p_i lnpi$ and p_i is the proportion of the ith species in the collection) was calculated for each year for each Geomorphic Reach. Coefficients of variation (CV = standard deviation/mean) were calculated for the abundance (fish/m^2) of each species each year in each Geomorphic Reach. Analysis of variance (ANOVA) was used to assess changes in abundance and Shannon-Wiener Diversity Index values within each Geomorphic Reach. For multiple ANOVA, the Tukey Honest Significant Difference test was applied to determine which comparisons were significantly different. The significance threshold for all statistical comparisons was ≤ 0.05.

Table 38. Attributes of summer discharge, San Juan River, 1993 – 1997.
Data from USGS Shiprock gage (#09368000).

	YEAR				
MONTH	1993	1994	1995	1996	1997
JULY	922	1020	3282	563	2164
AUGUST	1346	534	1561	491	2306
SEPTEMBER	1432	1078	1193	891	2361
MEAN DISCHARGE (CFS)[1]	1518	1271	2660	697	2524
DISCHARGE VOLUME (AC-FT)	197,228	129,298	271,127	101,116	350,970
DISCHARGE SPIKE DATA					
DAYS > 5000 CFS	0	0	0	0	4
DAYS > 4000 CFS	3	0	0	0	7
DAYS > 3000 CFS	4	0	0	0	18
DAYS > 2000 CFS	10	2	13	0	30
DAYS > 1000 CFS	35	15	53	22	66
DAYS < 1000 CFS	37	54	13	55	7
DAYS < 750 CFS	35	42	0	69	3
DAYS < 500 CFS	0	20	0	39	0
NUMBER DISCHARGE SPIKES	4	3	3	5	3
SPIKE DURATION (DAYS)	35	15	29	22	66
SPIKE MEAN (CFS)	1878	1437	1589	1253	2479
SPIKE VOLUME (AC-FT)	130,362	42,740	91,392	54,680	324,468

[1]Mean discharge data provided by Keller-Bliesner Engineering.

RESULTS

San Juan River secondary channels from RM 147.9 (Shiprock) downstream to
RM 68.7 (Chinle Creek) were sampled during autumn from 1994 through 1997. In 1993,
secondary channel sampling stopped at RM 76.5 (Sand Island). Sampling was conducted
in the first two weeks of October in all years except 1996 when it was done in the second
and third weeks of October. Number of secondary channels sampled within each
Geomorphic Reach ranged from a low of 4 (Reach 3 in 1993) to a high of 20 (Reach 3 in
1994). Typically, 10 to 15 secondary channels were sampled in each Reach in all years.
Mean daily discharge during each annual effort ranged from 717 in 1993 to 1479 cfs in
1997. In all years, except 1997, flows were fairly constant from early September through
late October (Figure 61). Two flow spikes (> 3000 cfs) occurred in 1997 between early
and late September. Mean daily discharge during summer (1 July through 30 September)
was lower in 1996 (751 cfs) than in any other year (1993 through 1997), but mean
autumn (1 – 31 October) discharge in 1996 (1181 cfs) was not substantially different
from other years.
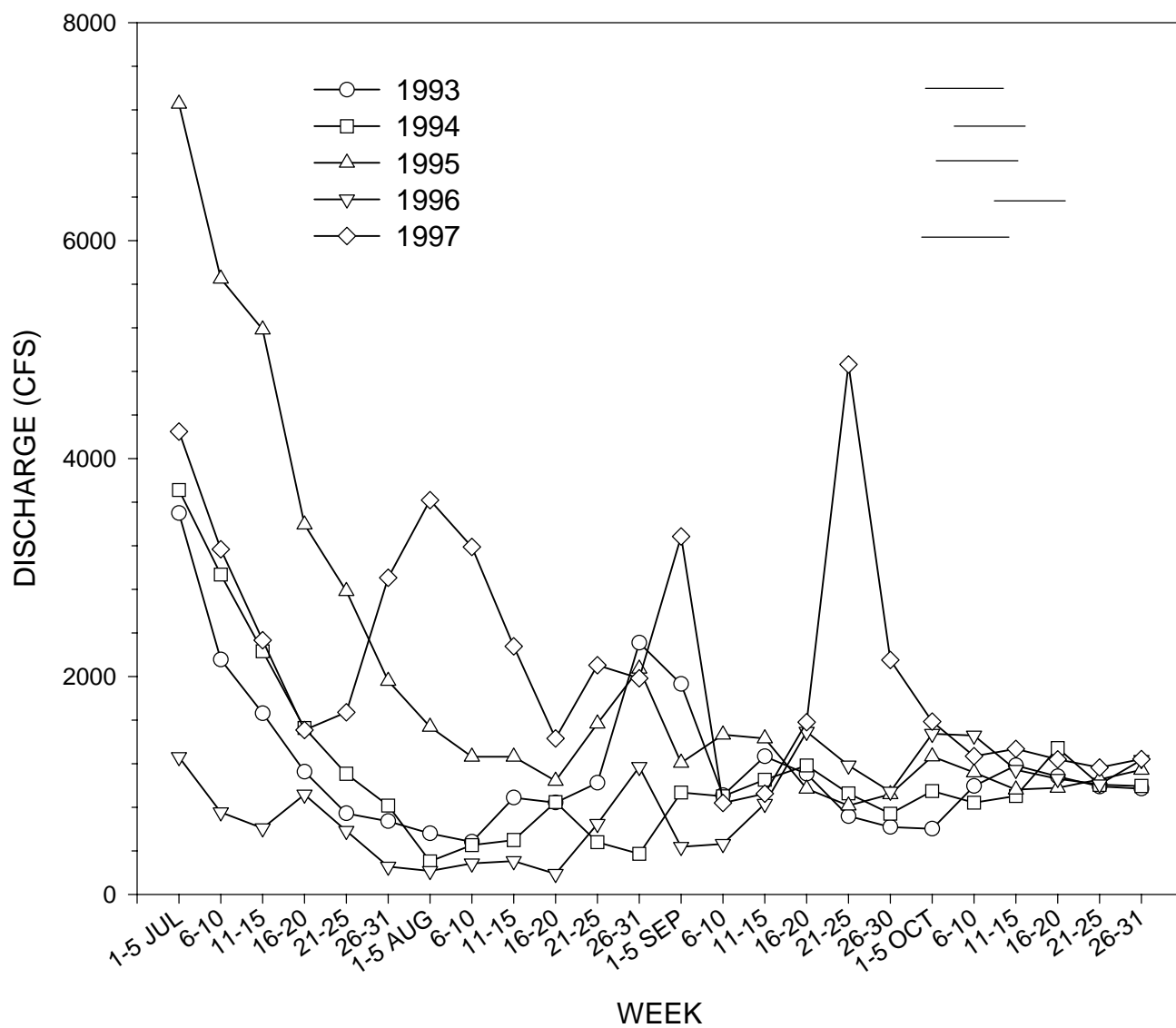
Figure 60. Mean weekly discharge (cfs) of San Juan River 1 July through 31 October, 1993-1997. Horizonal lines indicate time of autumn sampling.

Water Quality

During the study, mean autumn secondary channel water temperature varied from 10.2 in 1996 to 18.2°C in 1997. Water temperature was usually slightly higher in secondary channels than it was in the adjacent primary channel (Figure 62 and Table 39). Except for 1996, water temperature did not change longitudinally; in 1996 water temperature was higher in upstream than downstream reaches. At most sample locations there was negligible difference in secondary and primary channel dissolved oxygen levels (Figure 63). In 1993, 1994, and 1996, mean dissolved oxygen (primary and secondary channels) was comparatively high (> 9.0 mg/l), was near 8.0 mg/l in 1995, and only 6.7 mg/l in 1997. Considerable variation in dissolved oxygen was found in 1994, but little variation was noted for 1993, 1995, and 1997. Mean annual specific conductance was always greater in secondary channels than the primary channel. Spikes in specific conductance were more frequently found in secondary channels than the primary channel (Figure 64). In 1994, there was a slight downstream decreasing trend in specific conductance, but in other years readings were similar throughout the study reach.

Table 39. Mean values of water quality parameters of San Juan River secondary and primary channels during autumn inventories , 1993 – 1997. Values in parentheses are standard deviations.

YEAR	WATER TEMPERATURE (ºC)		DISSOLVED OXYGEN (mg/l)		CONDUCTIVITY (µmho/cm)	
	1°	2°	1°	2°	1°	2°
1993	15.9 (1.6)	16.3 (2.0)	10.3 (1.1)	10.1 (1.1)	633 (109)	661 (121)
1994	13.8 (1.3)	14.2 (1.7)	11.6 (1.8)	11.6 (2.1)	643 (110)	676 (145)
1995	12.5 (1.4)	13.0 (2.4)	7.6 (1.3)	7.8 (1.2)	424 (56)	459 (130)
1996	9.8 (2.2)	10.2 (2.4)	9.9 (0.9)	10.0 (1.3)	411 (40)	445 (106)
1997	17.8 (1.2)	18.2 (1.7)	6.7 (0.3)	6.7 (0.7)	417 (57)	430 (114)

Autumn Fish Assemblages

Fourteen species of fish, five native and nine nonnative, were collected in secondary channels during autumn inventories (Table 40). The greatest number of species was collected in 1997 (n = 13) and fewest (n = 9) in 1993. Abundance of fishes was highest in 1993 and lowest in 1997 (Table 41). Only three native species (speckled dace, flannelmouth sucker, and bluehead sucker) were collected each year of the study. In 1997, five native species were collected. All Colorado pikeminnow specimens collected in 1997 were likely stocked individuals. Roundtail chub was also found in 1997. Nonnative common carp, red shiner, fathead minnow, channel catfish, plains
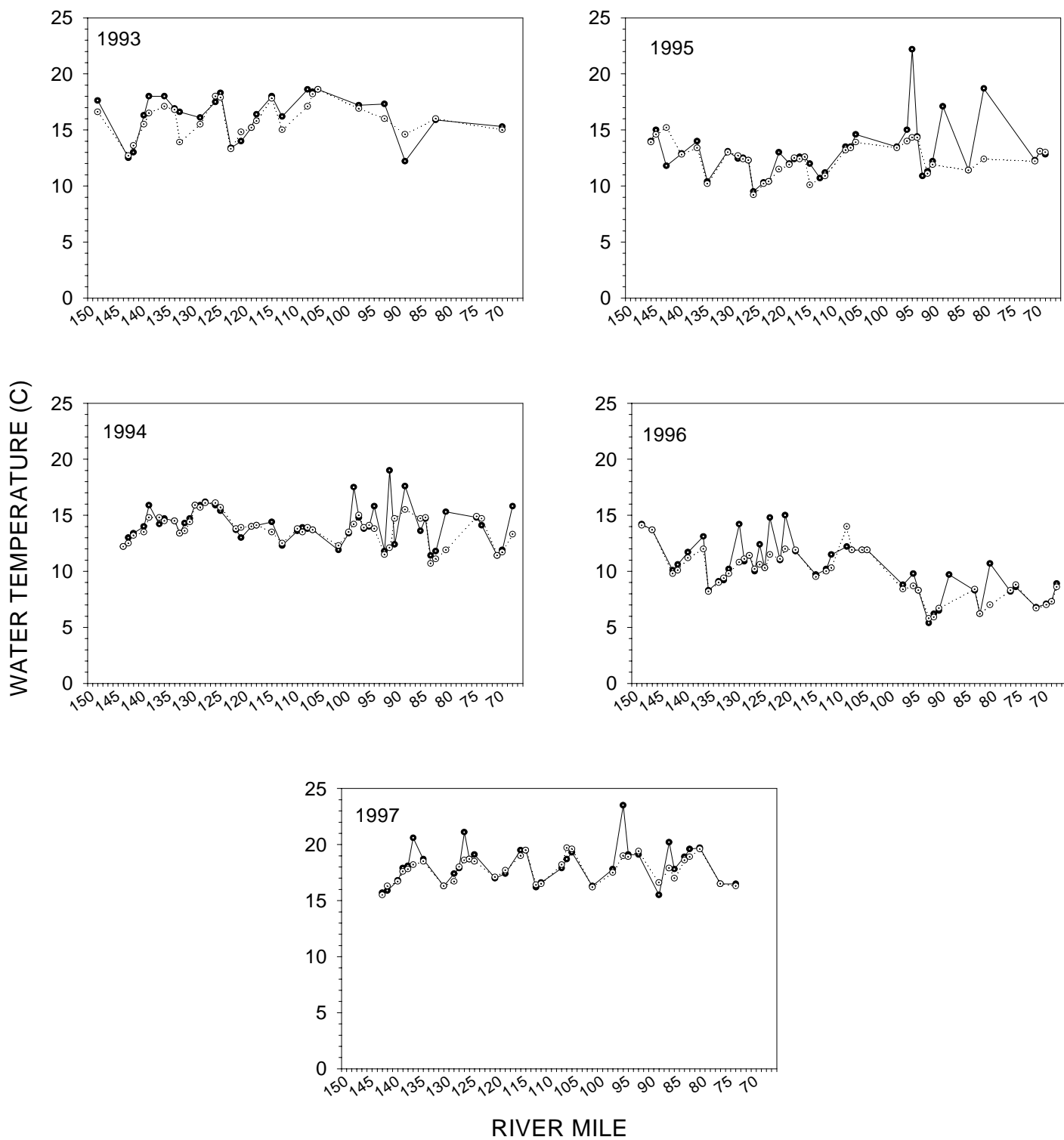
Figure 61. Water temperature of San Juan River secondary and primary channels during autumn inventories, 1993 - 1997.
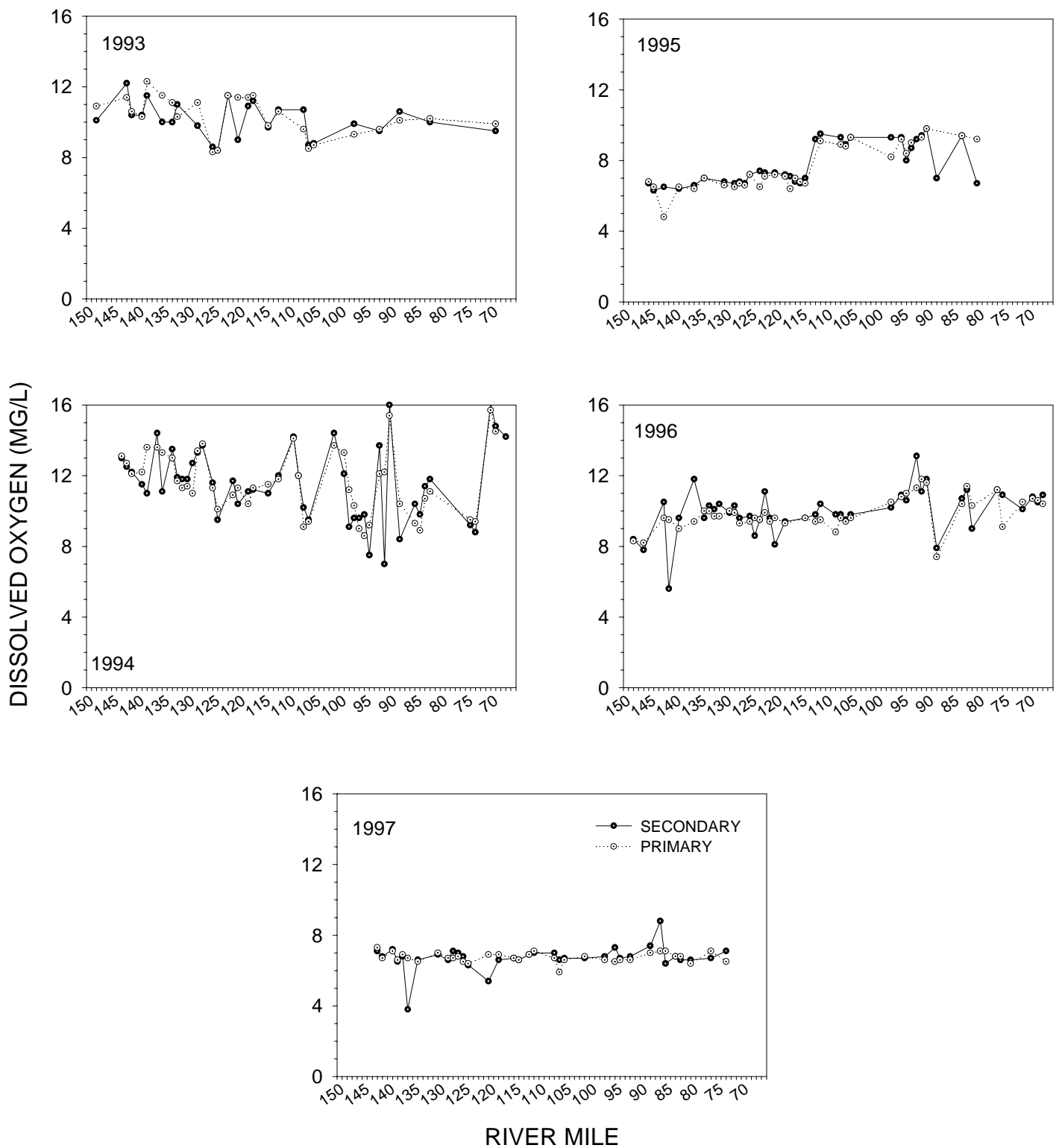
Figure 62. Dissolved oxygen (mg/l) of San Juan River secondary and primary channels during autumn inventories, 1993 - 1997.
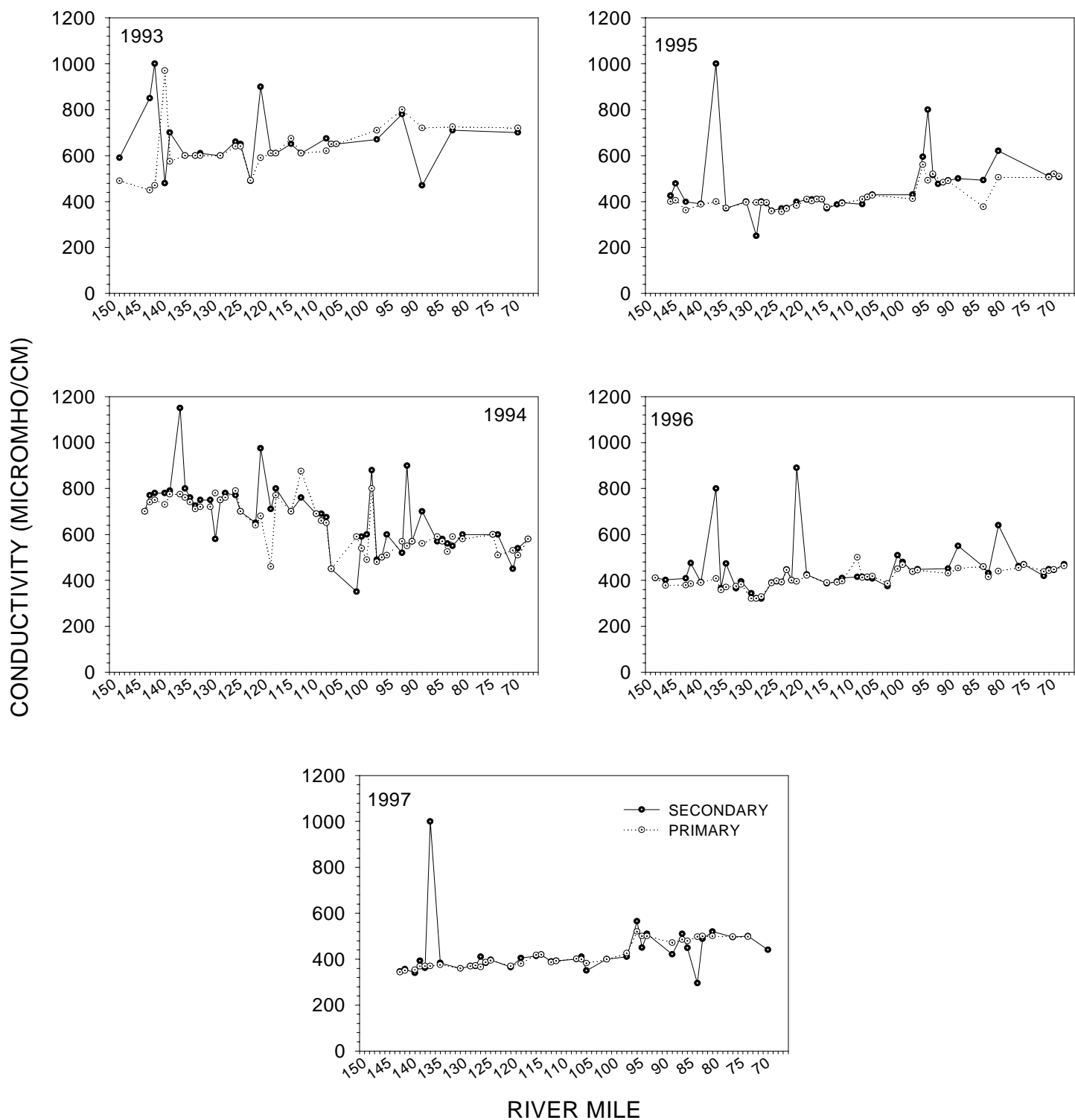
Figure 63. Conductivity (micromho/jcm) of San Juan River secondary and primary
channels during autumn inventories, 1993 - 1997.

109

Table 40. Occurrence of fishes in San Juan River secondary channels during autumn, 1993 – 1997. I = introduced and N = native. Six-letter codes derived from first three letters of genus and second three from species.

COMMON	SCIENTIFIC	CODE	STATUS	1993	1994	1995	1996	1997
Common carp	*Cyprinus carpio*	CYPCAR	I	X	X	X	X	X
Red shiner	*Cyprinella lutrensis*	CYPLUT	I	X	X	X	X	X
Roundtail chub	*Gila robusta*	GILROB	N					X
Fathead minnow	*Pimephales promelas*	PIMPRO	I	X	X	X	X	X
Colorado squawfish	*Ptychocheilus lucius*	PTYLUC	N					X
Speckled dace	*Rhinichthys osculus*	RHIOSC	N	X	X	X	X	X
Flannelmouth sucker	*Catostomus latipinnis*	CATLAT	N	X	X	X	X	X
Bluehead sucker	*Catostomus discobolus*	CATDIS	N	X	X	X	X	X
Black bullhead	*Ameiurus melas*	AMEMEL	I		X	X		
Channel catfish	*Ictalurus punctatus*	ICTPUN	I	X	X	X	X	X
Plains killifish	*Fundulus zebrinus*	FUNZEB	I	X	X	X	X	X
Western mosquitofish	*Gambusia affinis*	GAMAFF	I	X	X	X	X	X
Green sunfish	*Lepomis cyanellus*	LEPCYA	I		X	X	X	X
Largemouth bass	*Micropterus salmoides*	MICSAL	I		X	X	X	X
TOTAL NATIVE			5	3	3	3	3	5
TOTAL NONNATIVE			9	6	9	9	8	8

killifish, and western mosquitofish were found in all years. Sub-adults and adults of flannelmouth sucker, bluehead sucker, common carp, and channel catfish were rarely collected during autumn secondary channel surveys; most collected specimens of each species were 75 to 125 mm TL. Juveniles, sub-adults, and adults of red shiner, fathead minnow, speckled dace, and western mosquitofish were uncommon to common in each Geomorphic Reach. Age-0 (juveniles and sub-adults) of these species typically were more common than adults. Although collected each autumn, plains killifish was uncommon throughout the study reach in all years; most individuals were sub-adults or adults. Autumn sampling occurred after most, if not all, spawning activity. Few specimens of small-bodied species were < 35 mm TL (juveniles or younger).

Nonnative red shiner was the most common species in secondary channels in all years; its abundance was 1.65 to 2.46 times greater than the next most-common species. Native speckled dace was the second-most common species in 1993 and 1997 and was never less than fourth-most common. Nonnative fathead minnow was second-most common in 1994 and 1996 and, like speckled dace, was never less than fourth-most common. Abundance rank of western mosquitofish varied considerably from year to year, from third (1996) to ninth (1997). Abundance rank of native bluehead and flannelmouth suckers was never greater than fourth or less than eighth. There was a high level of concordance in abundance rank of species in autumn across years (Friedman's χ^2 = 33.94, $p < 0.0001$, W = 0.848).

Total abundance of fishes in secondary channels was relatively high from 1993 through 1995 (3.94 to 4.52 fish/m^2), but declined from 1996 (2.51 fish/m^2) to an autumn low in 1997 (0.76 fish/m^2; Figure 65). Assemblage diversity was highest in 1993 and
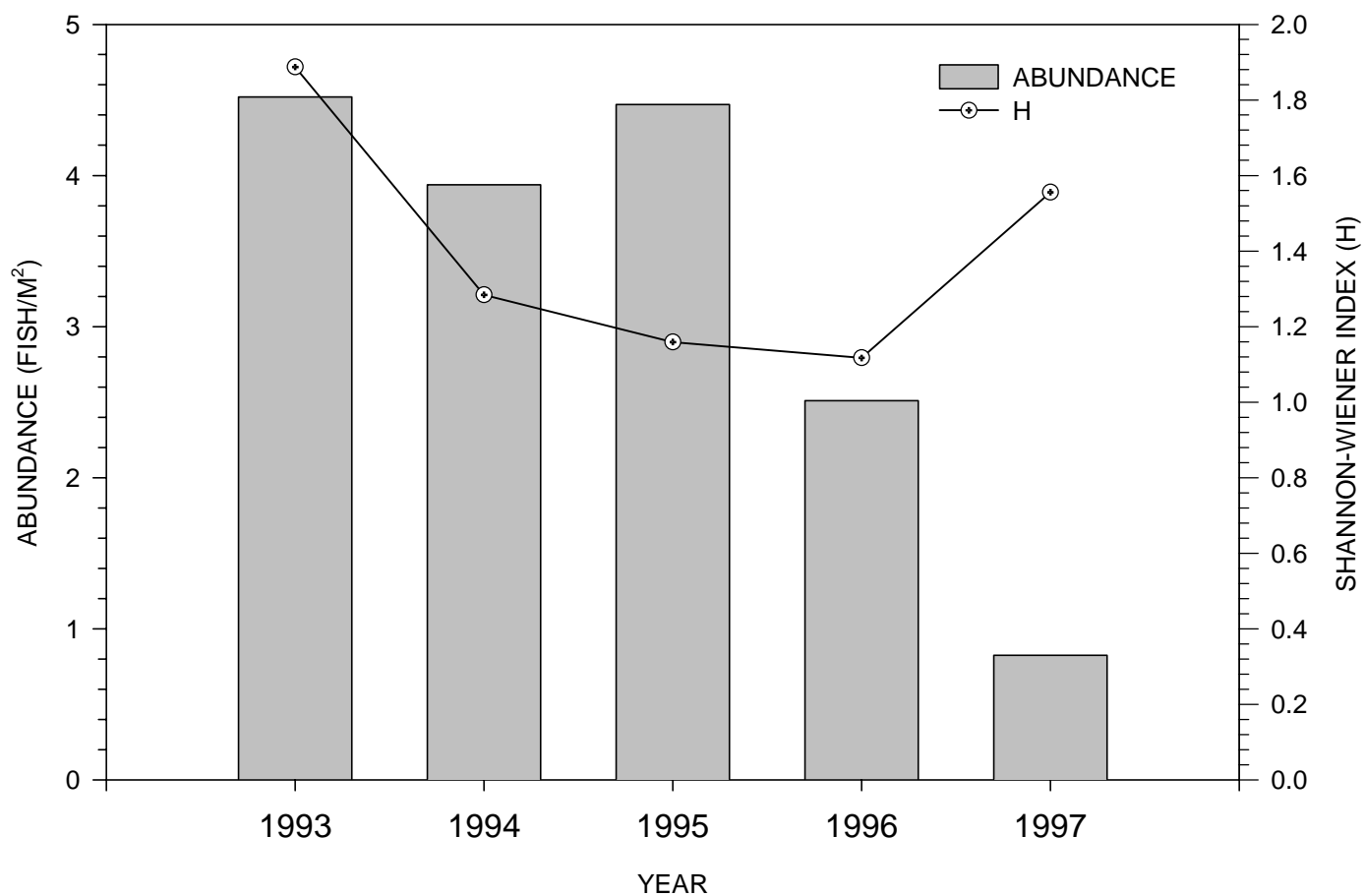
Figure 64. Abundance of fishes and Shannon-Wiener Diversity Index values
of fish assemblages in San Juan River secondary channels
(Geomorphic Reaches combined) during autumn,1993 - 1997.

Table 41. Fishes collected in San Juan River secondary channels (RM 149 – RM 68) during autumn inventories, 1993 – 1997. Bold-lettered species were used to calculate Kendall's coefficient of concordance (W).

1993		1994		1995		1996		1997	
SPECIES	N	SPECIES	N	SPECIES	N	SPECIES	N	SPECIES	N
CYPLUT	2427	**CYPLUT**	5397	**CYPLUT**	4125	**CYPLUT**	3632	**CYPLUT**	1023
RHIOSC	1090	**PIMPRO**	2196	**PIMPRO**	2417	**PIMPRO**	2201	**RHIOSC**	564
PIMPRO	699	**RHIOSC**	967	**RHIOSC**	987	**GAMAFF**	716	PTYLUC	241
CATLAT	189	**GAMAFF**	643	**GAMAFF**	135	**RHIOSC**	127	**PIMPRO**	175
CATDIS	164	**ICTPUN**	204	**ICTPUN**	62	**ICTPUN**	57	**CATLAT**	75
ICTPUN	97	**CATLAT**	192	**CATLAT**	57	**CATLAT**	31	**ICTPUN**	68
FUNZEB	65	**FUNZEB**	43	**CATDIS**	42	**CATDIS**	29	**CATDIS**	45
GAMAFF	45	**CATDIS**	20	**FUNZEB**	18	**FUNZEB**	17	**CYPCAR**	18
CYPCAR	7	MICSAL	10	**CYPCAR**	9	**CYPCAR**	1	**GAMAFF**	15
		CYPCAR	8	LEPCYA	2	LEPCYA	1	GILROB	11
		AMEMEL	3	MICSAL	1	MICSAL	1	**FUNZEB**	
		LEPCYA	1	AMEMEL	1			LEPCYA	1
								MICSAL	1
TOTAL N	4783		9684		7856		6813		2119
AREA	1058		2456		1758		2715		2681
ABUN	4.521		3.94		4.469		2.509		0.7904
H	1.8874		1.2844		1.1590		1.1173		1.558

lowest in 1996. In 1997, the year of lowest total abundance, diversity was the second-highest (H = 1.5558) found in autumn. The three most-abundant species, red shiner, fathead minnow, and speckled dace (all years except 1996 when western mosquitofish was third-most common) represented > 82% of the total collection each year (Figure 66). In 1996, nonnative species numerically dominated the collection (96% of total). Native fishes were least common (2.8%) in 1996 and most common in 1997 (39.0%). Abundance of red shiner was fairly constant from 1993 through 1995 (about 2.3/m^2), but diminished in 1996 and was lowest in 1997 (0.38/m^2). Speckled dace, flannelmouth sucker, and bluehead sucker abundance was highest in 1993 and lowest in 1996 (speckled dace and flannelmouth sucker) and 1994 (bluehead sucker). Total abundance was negatively, but not significantly, related to discharge at time of sampling ($r^2 = 0.768$, p <0.051).

Geomorphic Reach 5

Thirteen fish species, five native and eight nonnative, were collected in Reach 5 between 1993 and 1997 (Table 42). Colorado pikeminnow and roundtail chub were found in 1997, but not in prior years. Total abundance was comparatively high (> 6.0 fish/m^2) in 1993 and 1996 and was lowest (1.3 fish/m^2) in 1997. Red shiner was the most abundant species in all years except 1997 when speckled dace was most abundant . Fathead minnow and speckled dace were usually the second- or third-most abundant
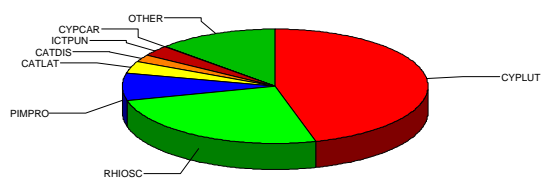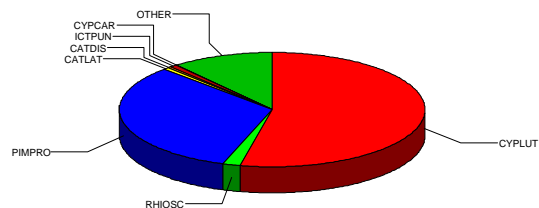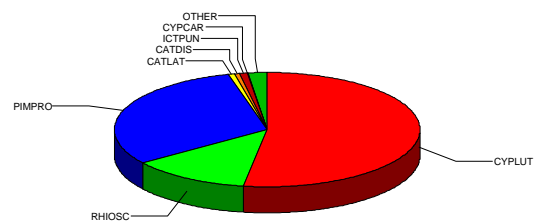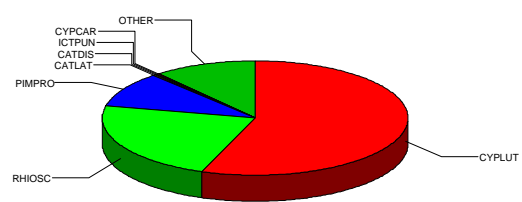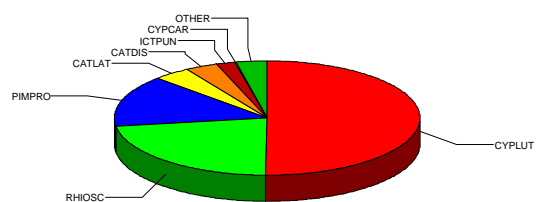
Figure 65. Relative abundance of commonly collected fishes during autumn in secondary channels, San Juan River, 1993 – 1997.

species. In 1997, Colorado pikeminnow was the third-most abundant species.
Abundance rank of species did not change appreciably from year to year; concordance of

Table 42. Number and abundance (number/m^2) of fishes in San Juan River secondary channels in Geomorphic Reach 5 (RM 154 – RM 131) during autumn, 1993 – 1997. Bold-lettered species used to calculate Kendall's coefficient of concordance.

1993			1994			1995			1996			1997		
SPECIES	N	ABU	SPECIES	N	ABU	SPECIES	N	ABU	SPECIES	N	ABU	SPECIES	N	ABU
CYPLUT	1028	2.62	**CYPLUT**	1066	1.16	**CYPLUT**	341	1.07	**CYPLUT**	1626	2.99	**RHIOSC**	292	0.40
PIMPRO	627	1.60	**PIMPRO**	695	0.76	**RHIOSC**	305	0.95	**PIMPRO**	1559	1.85	**CYPLUT**	292	0.40
RHIOSC	545	1.39	**RHIOSC**	541	0.59	**PIMPRO**	156	0.49	**GAMAFF**	501	0.92	PTYLUC	192	0.26
CATDIS	110	0.28	**GAMAFF**	268	0.29	**GAMAFF**	49	0.15	**RHIOSC**	63	0.12	**PIMPRO**	114	0.15
CATLAT	90	0.23	**ICTPUN**	74	0.08	**CATLAT**	35	0.11	**ICTPUN**	13	0.02	**CATLAT**	20	0.03
GAMAFF	44	0.11	**CATLAT**	50	0.05	**CATDIS**	26	0.08	**FUNZEB**	9	0.02	**ICTPUN**	16	0.02
FUNZEB	11	0.03	**FUNZEB**	26	0.03	**CYPCAR**	4	0.01	**CATLAT**	6	0.01	**CYPCAR**	16	0.02
ICTPUN	6	0.02	**CATDIS**	10	0.01	**ICTPUN**	2	0.01	**CATDIS**	4	0.01	**GAMAFF**	13	0.02
CYPCAR	3	0.01	MICSAL	9	0.01	LEPCYA	1	<0.01	**CYPCAR**	1	<0.01	**CATDIS**	12	0.02
			CYPCAR	2	<0.01	MICSAL	1	<0.01				GILROB	2	<0.01
												FUNZEB	2	<0.01
												Lepcya	1	<0.01
												Micsal	1	<0.01

TOTAL N	2464		2741		920		3782		971
AREA	392		920		320		544		738
ABU	6.286		2.979		2.875		6.952		1.316
H	1.425		1.521		1.468		1.118		1.650

rank was significant (Friedman's χ^2 = 31.68, *p* <0.0001, W = 0.792). From 1993 through 1995, assemblage diversity was essentially constant (H = 1.5), declined in 1996 (H = 1.1), and increased to the study high (H = 1.6) in 1997 (Figure 67). The relationship between discharge at time of sampling and total fish abundance was negative, but not significant (r^2 = 0.3899, *p* < 0.26).

As a proportion of the collections in Reach 5, red shiner was the most abundant species in all years except 1997, and then it was only slightly less common than speckled dace (Figure 68). Speckled dace was > 20% of the collection in all years except 1996, when it was 1.7%. Fathead minnow relative abundance peaked (41%) in 1996. In 1997, Colorado squawfish was 19.8% of the specimens collected in Reach 5.

The coefficient of variation (CV) of abundance (fish/m^2) of fish species collected each year in Reach 5 secondary channels was moderately high (0.50 to 0.75) to high (> 0.75). Abundant species had lower CVs than less abundant ones; there was a general trend of increasing CV with decreasing abundance (Figure 69).

Figure 66. Abundance of fishes and Shannon-Wiener Diversity Index values
of fish assemblages during autumn in Geomorphic Reach 5,
San Juan River, 1993 - 1997.

1993

1994

1995

1996
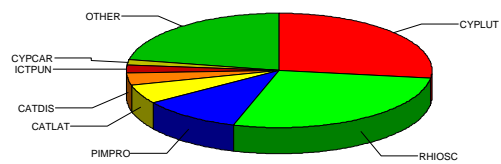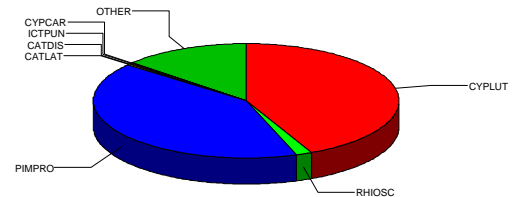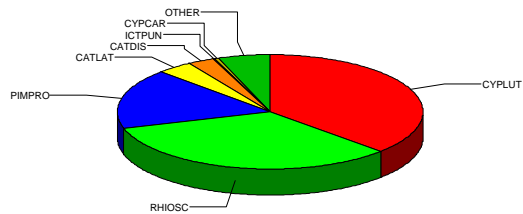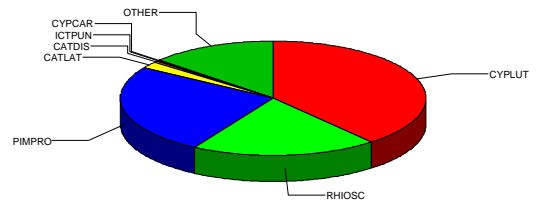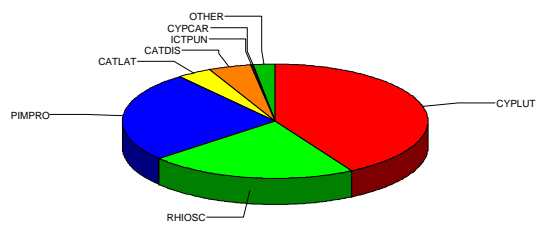
1997

Figure 67. Relative abundance of commonly collected fishes during autumn in Geomorphic Reach 5, San Juan River, 1993 – 1997.
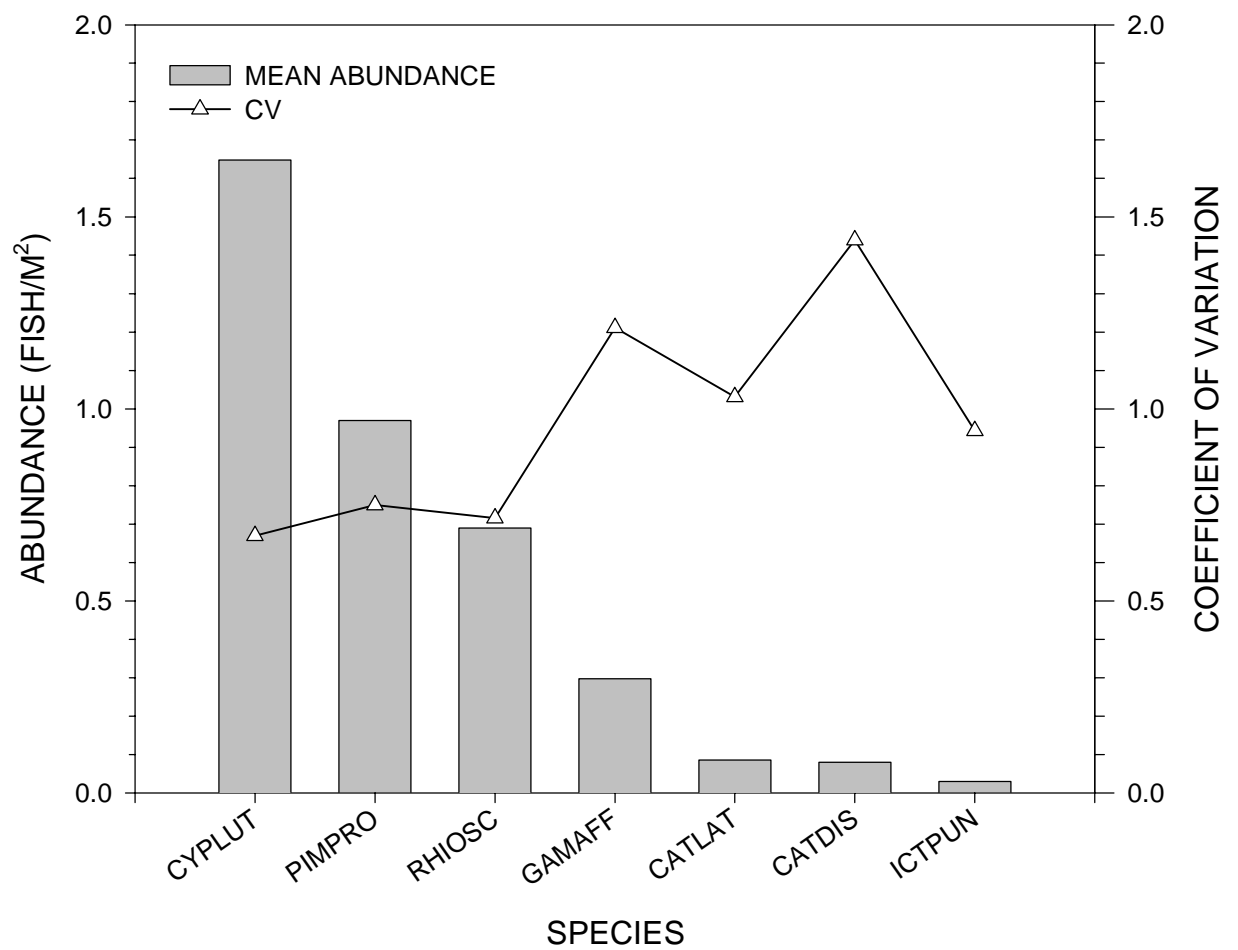
Figure 68. Mean abundance (1993 - 1997) and coefficient of variation (CV) in abundance of fish species commonly collected during autumn in Geomorphic Reach 5, San Juan River, 1993 - 1997.

Autumn abundance of red shiner, fathead minnow, speckled dace, flannelmouth sucker, bluehead sucker, channel catfish, and western mosquitofish was compared to 10 attributes of summer discharge. Autumn abundance of red shiner was not significantly related to any summer discharge attribute (Table 43). The general pattern was a negative response in red shiner abundance to elevated summer flows (e.g., volume and days flow

Table 43. Results of linear regression analysis of relationship between summer discharge Attributes and autumn secondary channel abundance of red shiner, *Cyprinella lutrensis*, in Geomorphic Reach 5, San Juan River, 1993 – 1997.

SUMMER DISCHARGE ATTRIBUTE	r^2	r	*p*
SUMMER DISCHARGE VOLUME (AC-FT)	0.5350	0.7314	0.16
SUMMER MEAN DISCHARGE (CFS)	0.5354	0.7317	0.16
DAYS >2000 CFS	0.4785	0.6918	0.20
DAYS >1000 CFS	0.3702	0.6084	0.28
DAYS <1000 CFS	0.4613	0.6792	0.21
DAYS <500 CFS	0.3038	0.5512	0.34
FLOW SPIKE DURATION (DAYS)	0.2480	0.4980	0.39
FLOW SPIKE MEAN (CFS)	0.3307	0.5751	0.31
FLOW SPIKE VOLUME (AC-FT)	0.3080	0.5549	0.33

1000 cfs) and a positive response to low summer flows (e.g., days flow < 500 cfs). Figure 70 illustrates the relationship between red shiner abundance and one summer flow attribute. The relationship of fathead minnow autumn abundance to summer flow attributes was similar to that of red shiner (Table 44). Fathead minnow abundance was less during in years with high summer flows than in years with low summer flows; the strongest negative relationship was with mean summer discharge (Figure 70). Fathead minnow autumn abundance was positively, but not significantly, related to days flow < 500 cfs.

Table 44. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of fathead minnow, *Pimephales promelas*, in Geomorphic Reach 5, 1993 – 1997.

SUMMER DISCHARGE ATTRIBUTES	r^2	r	*p*
SUMMER DISCHARGE VOLUME (AC-FT)	0.6022	0.7761	0.12
SUMMER MEAN DISCHARGE (CFS)	0.6026	0.7763	0.12
DAYS >2000 CFS	0.5178	0.7196	0.17
DAYS >1000 CFS	0.4467	0.6683	0.22
DAYS <1000 CFS	0.5481	0.7404	0.15
DAYS <500 CFS	0.3497	0.5913	0.29
FLOW SPIKE DURATION (DAYS)	0.2696	0.5192	0.37
FLOW SPIKE MEAN (CFS)	0.3393	0.5825	0.30
FLOW SPIKE VOLUME (AC-FT)	0.3195	0.5653	0.32
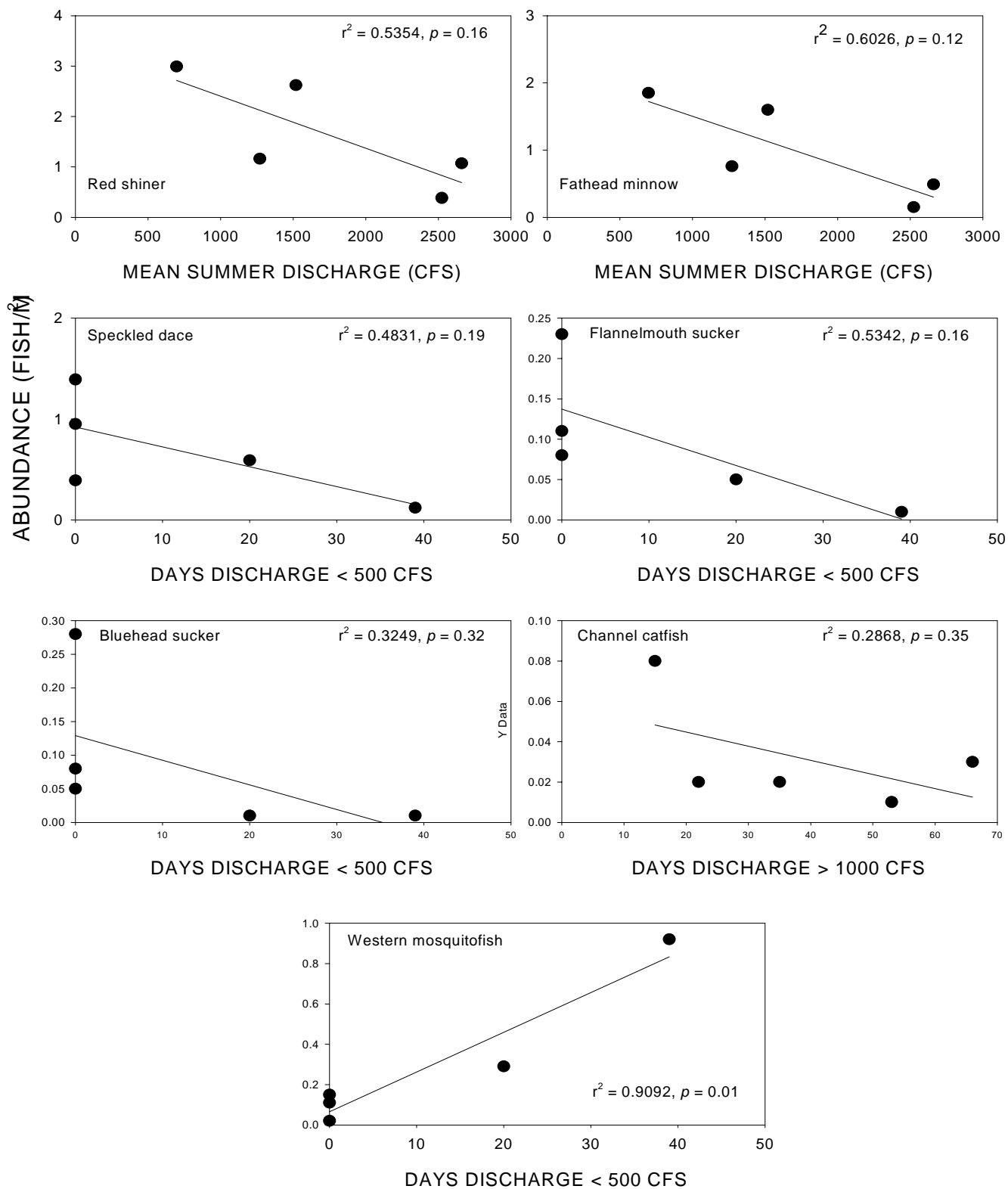
Figure 69. Autumn abundance of commonly collected fish species in Geomorphic Reach 5 versus summer flow attributes, San Juan River, 1993 - 1997.

There was essentially no relationship between speckled dace abundance and elevated summer flows (Table 45). There was a negative, but not significant, relationship between speckled dace abundance and days flow < 500 cfs (Figure 70). Overall, there was no relationship between any attribute of summer discharge and flannelmouth sucker or bluehead sucker autumn abundance (Tables 46 and 47). The strongest , and negative, was with days flow < 500 cfs (Figure 70). Abundance of channel catfish was not related to any attribute of summer discharge (Table 48 and Figure 70). Western mosquitofish abundance was negatively, but not significantly, related to elevated summer flows (Table 49) and was significantly, and positively, related to days flow < 500 cfs (Figure 70).

Table 45. Results of linear regression analysis of relationship between summer discharge Attributes and autumn secondary channel abundance of speckled dace, *Rhinichthys osculus*, in Geomorphic Reach 5, San Juan River, 1993 – 1997.

SUMMER DISCHARGE ATTRIBUTES	r^2	r	*p*
SUMMER DISCHARGE VOLUME (AC-FT)	0.0292	0.1710	0.78
SUMMER MEAN DISCHARGE (CFS)	0.0292	0.1708	0.78
DAYS >2000 CFS	0.0030	0.0546	0.93
DAYS >1000 CFS	0.0131	0.1146	0.85
DAYS <1000 CFS	0.0431	0.2075	0.74
DAYS <500 CFS	0.4831	0.6951	0.19
FLOW SPIKE DURATION (DAYS)	0.0014	0.0375	0.95
FLOW SPIKE MEAN (CFS)	0.0228	0.1511	0.81
FLOW SPIKE VOLUME (AC-FT)	0.0053	0.0725	0.91

Table 46. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of flannelmouth sucker, *Catostomus latipinnis*, Geomorphic Reach 5, San Juan River, 1993 – 1997.

SUMMER DISCHARGE ATTRIBUTES	r^2	r	*p*
SUMMER DISCHARGE VOLUME (AC-FT)	0.0844	0.2905	0.64
SUMMER MEAN DISCHARGE (CFS)	0.0842	0.2903	0.64
DAYS >2000 CFS	0.0569	0.2386	0.70
DAYS >1000 CFS	0.0639	0.2529	0.68
DAYS <1000 CFS	0.0849	0.2913	0.63
DAYS < 500 CFS	0.5342	0.7308	0.16
FLOW SPIKE DURATION (DAYS)	0.0490	0.2214	0.72
FLOW SPIKE MEAN (CFS)	0.1425	0.3775	0.53
FLOW SPIKE VOLUME (AC-FT)	0.0323	0.1798	0.77

Table 47. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of bluehead sucker, *Catostomus discobolus*, Geomorphic Reach 5, San Juan River, 1993 – 1997.

SUMMER DISCHARGE ATTRIBUTE	r^2	r	*p*
SUMMER DISCHARGE VOLUME (AC-FT)	0.0198	0.1406	0.82
SUMMER MEAN DISCHARGE (CFS)	0.0197	0.1403	0.82
DAYS >2000 CFS	0.0138	0.1196	0.85
DAYS >1000 CFS	0.0181	0.1345	0.83
DAYS <1000 CFS	0.0202	0.1423	0.82
DAYS < 500 CFS	0.3249	0.5700	0.32
FLOW SPIKE DURATION (DAYS)	0.0260	0.1612	0.80
FLOW SPIKE MEAN (CFS)	0.0807	0.2841	0.64
FLOW SPIKE VOLUME (AC-FT)	0.0120	0.1098	0.86

Table 48. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of channel catfish, *Ictalurus punctatus*, Geomorphic Reach 5, San Juan River, 1993 – 1997.

SUMMER DISCHARGE ATTRIBUTES	r^2	r	*p*
SUMMER DISCHARGE VOLUME (AC-FT)	0.1258	0.3547	0.56
SUMMER MEAN DISCHARGE (CFS)	0.1255	0.3543	0.56
DAYS >2000 CFS	0.0783	0.2797	0.65
DAYS >1000 CFS	0.2868	0.5356	0.35
DAYS <1000 CFS	0.2272	0.4767	0.42
DAYS < 500 CFS	0.0642	0.2533	0.68
FLOW SPIKE DURATION (DAYS)	0.1126	0.3356	0.58
FLOW SPIKE MEAN (CFS)	0.0257	0.1602	0.80
FLOW SPIKE VOLUME (AC-FT)	0.0494	0.2223	0.72

Table 49. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of western mosquitofish, *Gambusia affinis*, Geomorphic Reach 5, San Juan River, 1993 – 1997.

SUMMER DISCHARGE ATTRIBUTE	r^2	r	p
SUMMER DISCHARGE VOLUME (AC-FT)	0.5802	0.7617	0.14
SUMMER DISCHARGE MEAN (CFS)	0.5802	0.7617	0.14
DAYS > 2000 CFS	0.4992	0.7065	0.18
DAYS > 1000 CFS	0.3924	0.6265	0.26
DAYS < 1000 CFS	0.5009	0.7077	0.18
DAYS < 500 CFS	0.9092*	0.9535	0.01
FLOW SPIKE DURATION (DAYS)	0.3026	0.5501	0.34
FLOW SPIKE MEAN (CFS)	0.5434	0.7372	0.16
FLOW SPIKE VOLUME (AC-FT)	0.3261	0.5711	0.32

Geomorphic Reach 4

Between 1993 and 1997, 14 species of fish (five native and nine nonnative) were found in Reach 4 (Table 50). Six species (red shiner, fathead minnow, speckled dace, flannelmouth sucker, channel catfish, and western mosquitofish) were collected in all years. Western mosquitofish was represented by single specimens in 1993 and 1997. Bluehead sucker was not collected in 1996, plains killifish was absent in 1995 and 1997, and common carp was not found in 1993 or 1996. Colorado pikeminnow and roundtail chub were found in 1997. Red shiner was the most abundant species in all years. Speckled dace was second-most abundant in 1993, 1995, and 1997 and fathead minnow was second-most abundant in 1994 and 1996. The abundance rank of other species varied from year to year. For example, western mosquitofish went from least abundant species in 1993 to fourth-most abundant in 1994, was third or fourth through 1996, and was again the least abundant in 1997. Despite some shifts in abundance rank of several species, there was high concordance of rank among years (Friedman's $\chi^2 = 30.05$, $p < 0.0001$, W = 0.776). From 1993 through 1996, total abundance of fishes in Reach 4 declined slightly, but was substantially less in 1997 than in preceding years (Figure 71). Shannon-Wiener Diversity Index values changed little from year to year and was highest in 1997. Discharge at time of sampling versus total abundance of fishes in Reach 4 was not related ($r^2 = 0.274$, $p = 0.468$).

Table 50. Number and abundance (number/m^2) of fishes in San Juan River secondary channels in Geomorphic Reach 4 (RM 130 –RM 106) during autumn, 1993 – 1997. Bold-lettered species used to calculate Kendall's coefficient of concordance.

	1993			1994			1995			1996			1997		
SPECIES	N	ABUN	SPECIES	N	ABUN	SPECIES	N	ABUN	SPECIES	N	ABUN	SPECIES	N	ABUN
CYPLUT	1084	2.34	**CYPLUT**	1459	1.96	**CYPLUT**	1340	1.51	**CYPLUT**	1046	1.87	**CYPLUT**	203	0.21
RHIOSC	472	1.02	**PIMPRO**	657	0.88	**RHIOSC**	479	0.54	**PIMPRO**	473	0.84	**RHIOSC**	114	0.12
CATLAT	68	0.15	**RHIOSC**	164	0.22	**PIMPRO**	220	0.25	**GAMAFF**	188	0.34	**ICTPUN**	20	0.02
CATDIS	54	0.12	**GAMAFF**	145	0.19	**GAMAFF**	66	0.07	**RHIOSC**	37	0.07	**PIMPRO**	14	0.01
PIMRPO	45	0.10	**ICTPUN**	50	0.07	**ICTPUN**	34	0.04	**ICTPUN**	25	0.05	PTYLUC	9	0.01
ICTPUN	24	0.05	**CATLAT**	20	0.03	**CARLAT**	15	0.02	**CATLAT**	4	0.01	**CATLAT**	7	0.01
FUNZEB	7	0.02	**FUNZEB**	9	0.01	**CATDIS**	6	0.01	**FUNZEB**	3	0.01	**CATDIS**	6	0.01
GAMAFF	1	<0.01	**CATDIS**	4	0.01	**CYPCAR**	1	<0.01	LEPCYA	1	<0.01	GILROB	5	0.01
			CYPCAR	4	0.01	**FUNZEB**	1	<0.01	MICSAL	1	<0.01	**CYPCAR**	1	<0.01
			AMEMEL	1	<0.01							**GAMAFF**	1	<0.01
			LEPCYA	1	<0.01									
			MICSAL	1	<0.01									

TOTAL N	1755			2515			2162			1778			380		
AREA	464			744			888			560			960		
ABUN	3.782			3.380			2.435			3.175			0.396		
H	1.062			1.176			1.093			1.075			1.272		

For most commonly collected species in Reach 4, there was an inverse relationship between abundance of each and their respective coefficient of variation
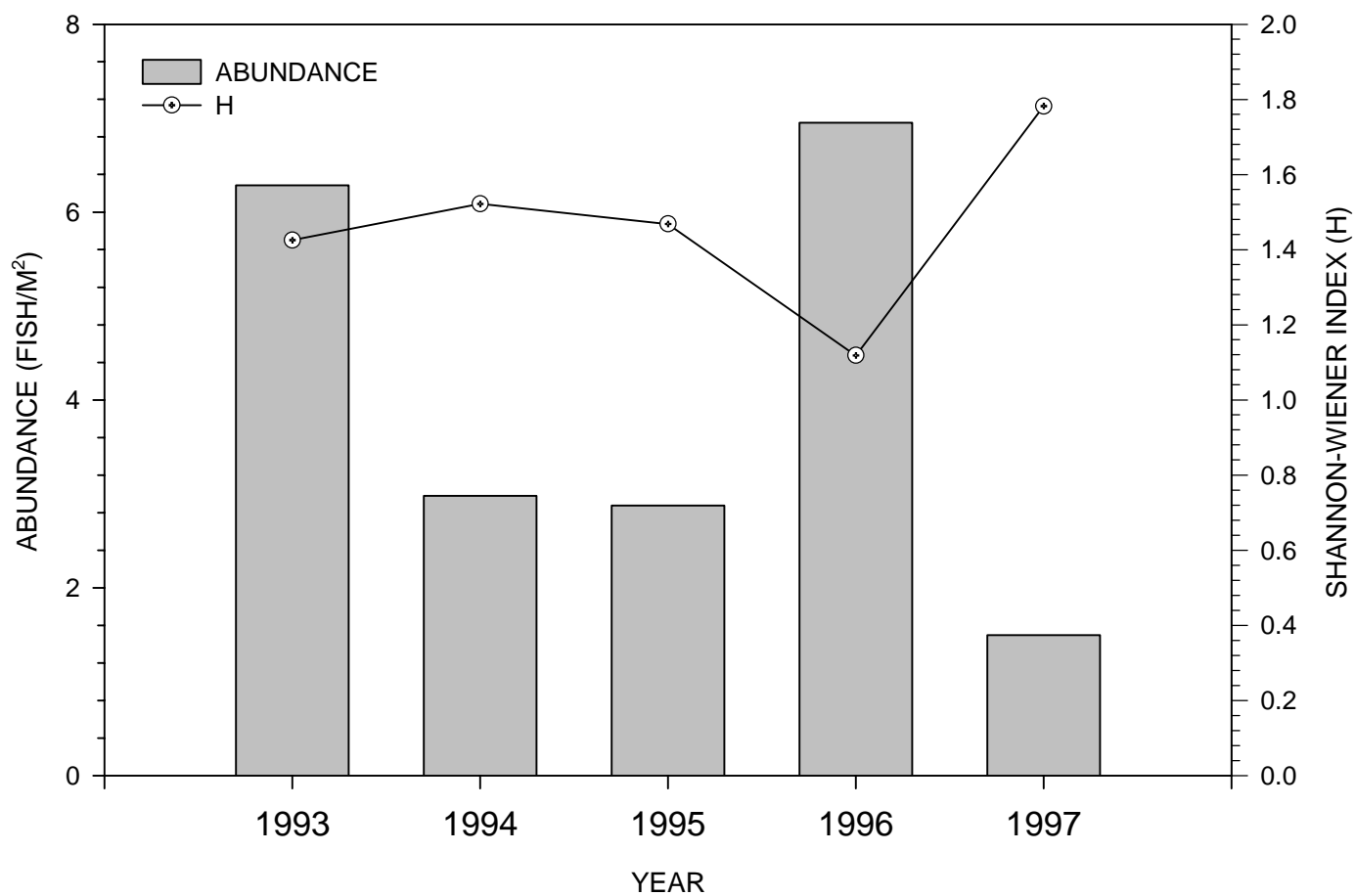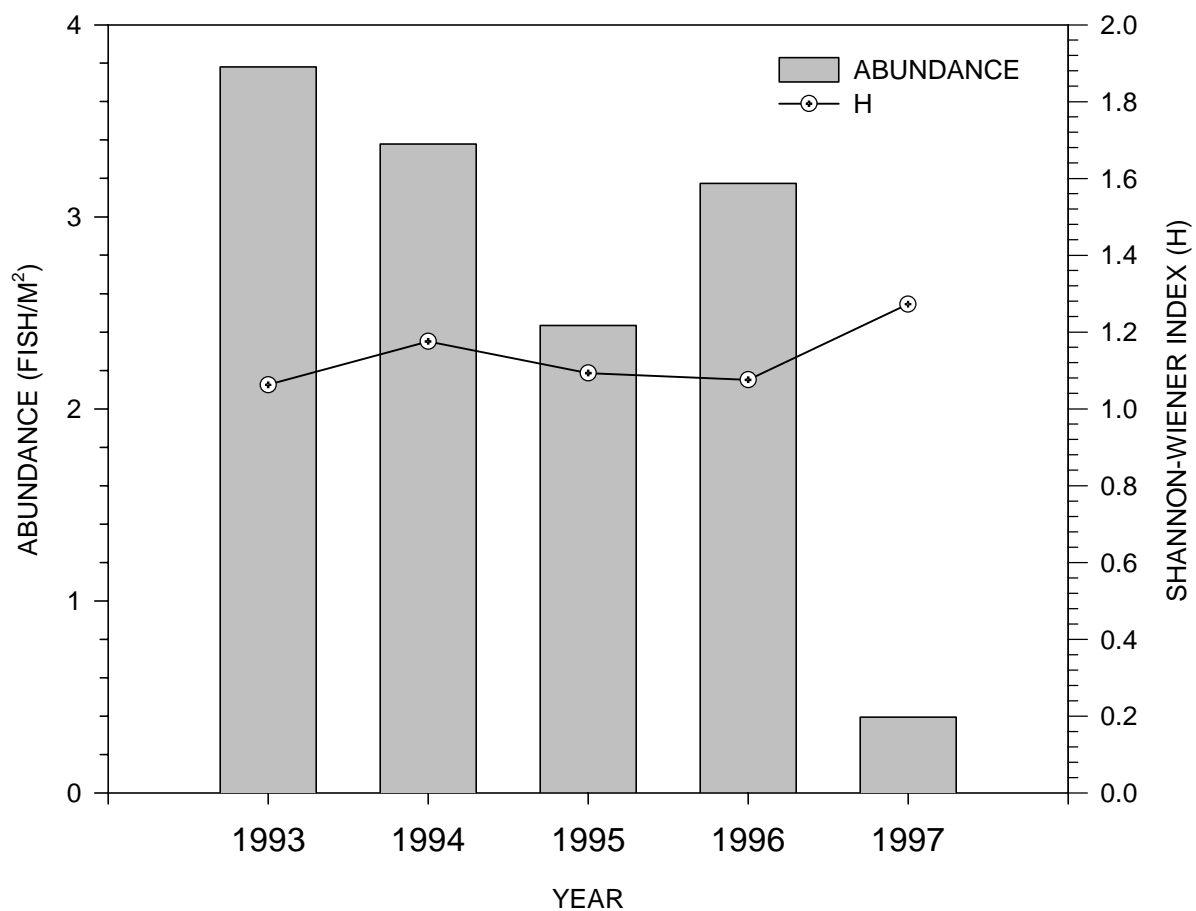
Figure 70. Abundance of fishes and Shannon-Wiener Diversity Index values of fish assemblages during autumn in Geomorphic Reach 4, San Juan River, 1993 - 1997.

(Figure 72). Thus, the most abundant species had comparatively low CVs in contrast to less abundant species with high CVs. The outstanding exception to this pattern was channel catfish; both its abundance and CV were low.

In 1993, 1995, and 1997, native fishes were 23% or more of each year's collection in Reach 4 (Figure 73). In 1994 and 1996, native fishes were 7.5 and 2.3% of the collections. Red shiner was the large majority of nonnative fishes collected in 1993, 1995, and 1997. In 1994 and 1996, fathead minnow was about 26% of each year's collection. Relative abundance of flannelmouth and bluehead suckers was highest in 1993 and 1997. Channel catfish generally represented a small proportion ($< 2\%$) of each year's collection, but in 1997 was 5% of the total collection. Colorado pikeminnow was 2.4% of the 1997 collection.

The autumn abundance of several nonnative species was significantly related to several attributes of summer discharge. Although none were significant, the autumn abundance of red shiner in Reach 4 was fairly strongly, and negatively, related to several summer discharge attributes (Table 51). The only summer discharge attribute not related

Table 51. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of red shiner, *Cyprinella lutrensis*, in Geomorphic Reach 4, 1993 – 1997.

SUMMMER DISCHARGE ATTRIBUTES	r^2	r	*p*
Summer discharge volume (ac.ft.)	0.6405	0.8004	0.10
Summer discharge mean (cfs)	0.6408	0.8005	0.10
Days >2000 cfs	0.7368	0.8584	0.06
Days >1000 cfs	0.6258	0.7911	0.11
Days <1000 cfs	0.5464	0.7392	0.15
Days < 500 cfs	0.1100	0.3316	0.59
Flow spiked duration (days)	0.6840	0.8270	0.08
Flow spike mean (cfs)	0.5403	0.7351	0.16
Flow spike volume (ac.ft.)	0.7175	0.8470	0.07

was days flow < 500 cfs. Most attributes were similar to that illustrated in Figure 74. Fathead minnow abundance was negatively, but not significantly, related to most attributes of summer discharge (Table 52). The outstanding exception was days flow $<$ 500 cfs; it was positively, and significantly, related to autumn abundance (Figure 74). Summer discharge attributes were generally not related to the three commonly collected native fish species. The strongest relationship between autumn speckled dace abundance and summer discharge was the negative relationship with days flow < 500 cfs (Table 53, Figure 74). The relationships of flannelmouth and bluehead suckers abundance with summer discharge (Tables 54 and 55) were similar to, but weaker than, those involving speckled dace. Abundance of the two sucker species was negatively related to days flow

124
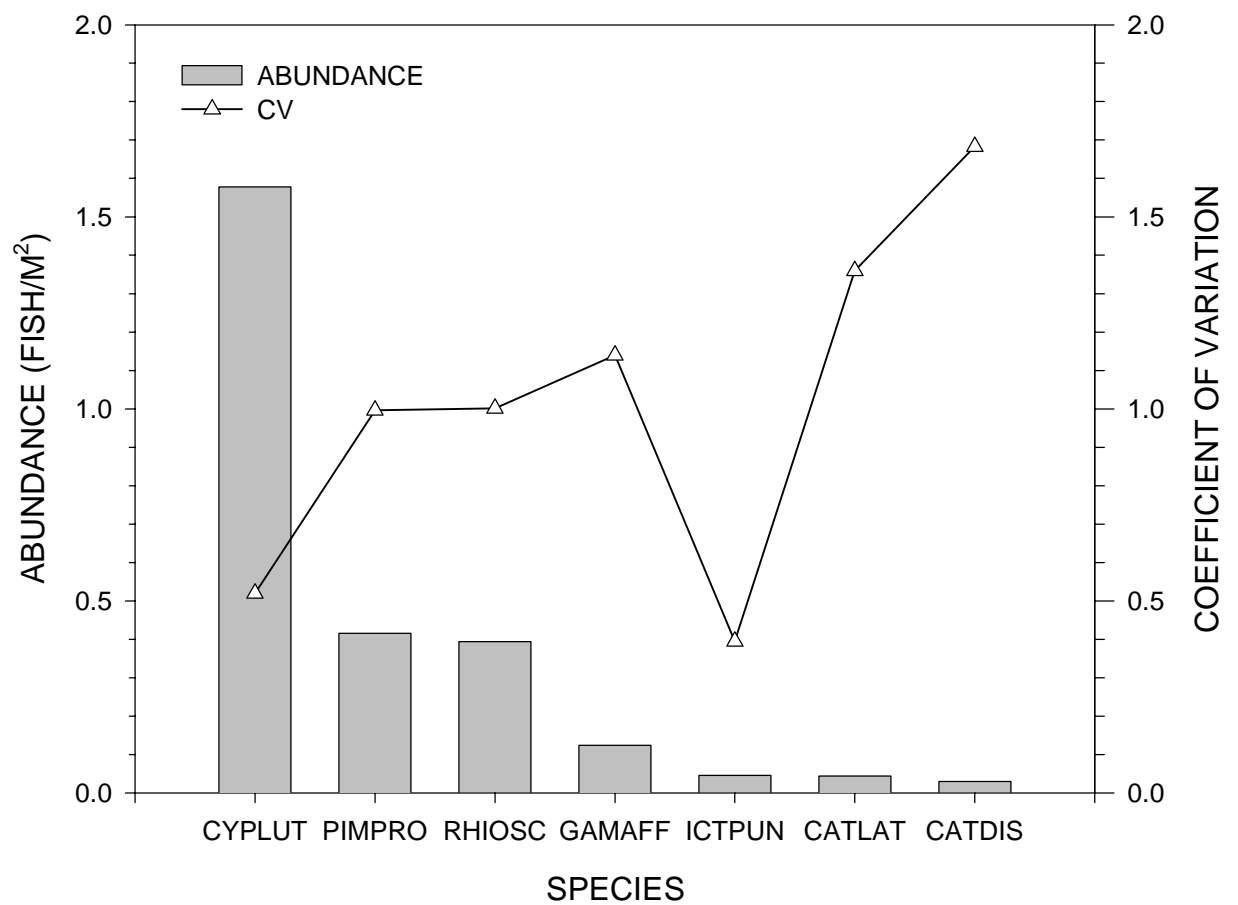
Figure 71. Mean abundance (1993 - 1997) and coefficient of variation (CV)
of abundance of fish species commonly collected during autumn in
Geomorphic Reach 4, San Juan River, 1993 - 1997.
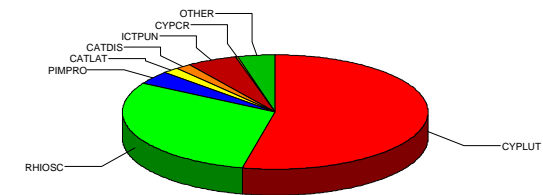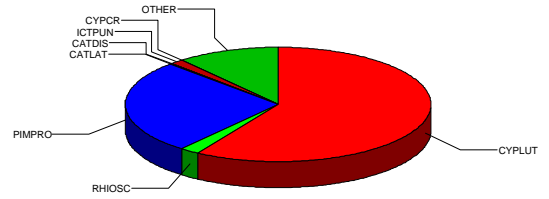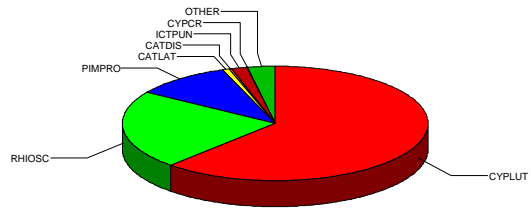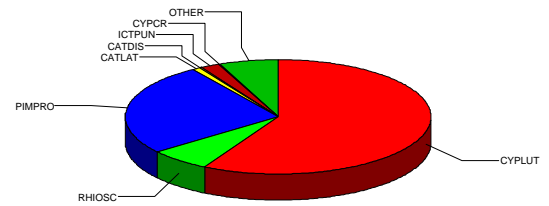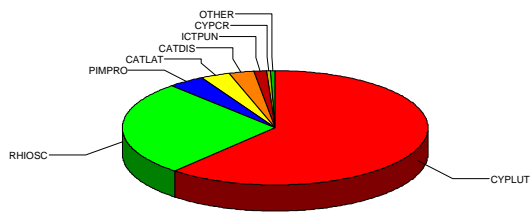
Figure 72. Relative abundance of commonly collected fishes during autumn in Geomorphic Reach 4, San Juan River, 1993 – 1997.
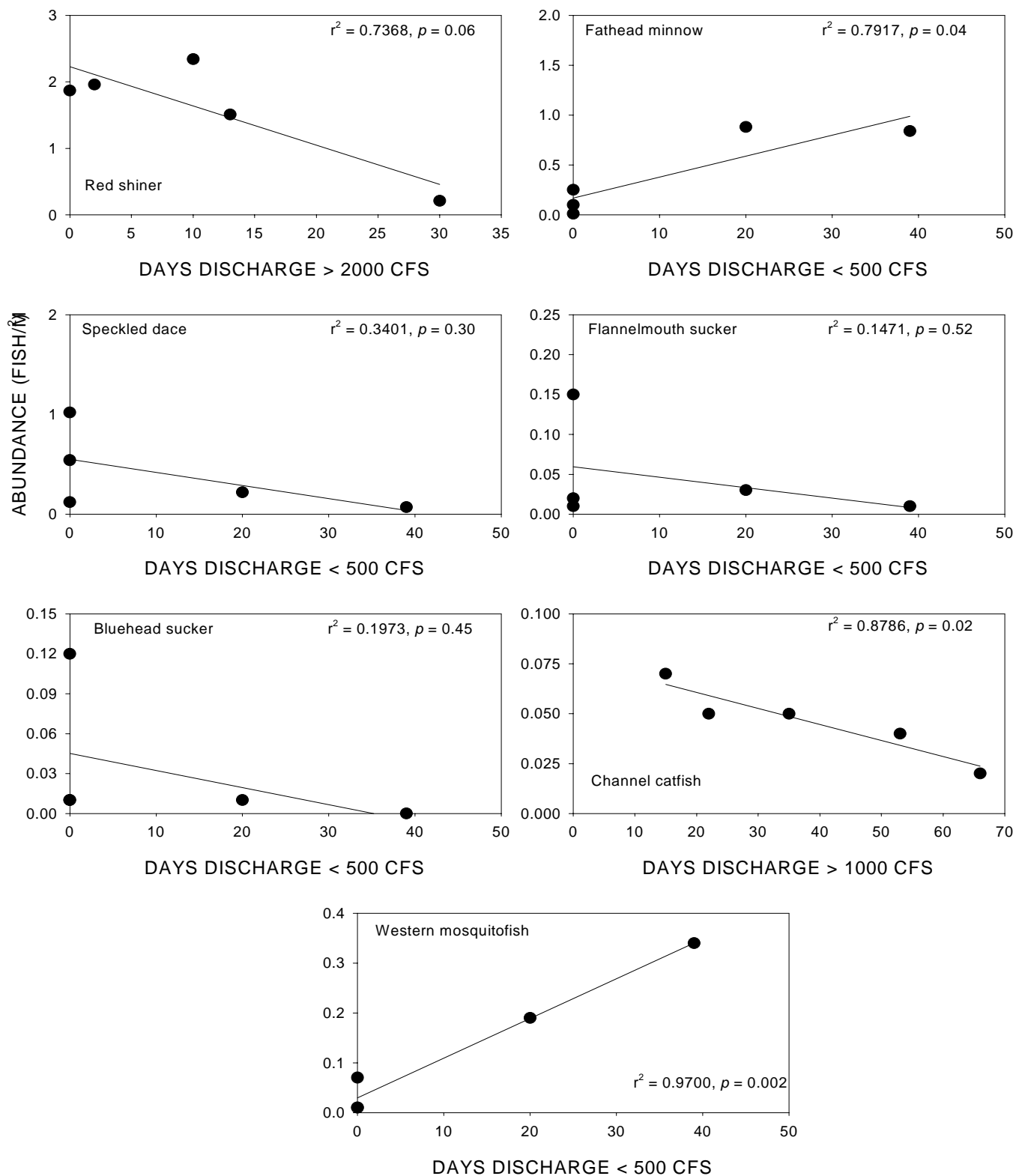
Figure 73. Autumn abundance of fishes in Geomorphic Reach 4 versus attributes of summer discharge, San Juan River, 1993 - 1997.

127

Table 52. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of fathead minnow, *Pimephales promelas*, in Geomorphic Reach 4, 1993 – 1997. An asterisk indicates a significant relationship.

SUMMMER DISCHARGE ATTRIBUTES	r^2	r	*P*
Summer discharge volume (ac.ft.)	0.7456	0.8635	0.06
Summer discharge mean (cfs)	0.7453	0.8633	0.06
Days >2000 cfs	0.7033	0.8386	0.08
Days >1000 cfs	0.7442	0.8+626	0.06
Days <1000 cfs	0.7242	0.8510	0.07
Days < 500 cfs	0.7917*	0.8898	0.04
Flow spiked duration (days)	0.6520	0.8074	0.10
Flow spike mean (cfs)	0.7037	0.8389	0.08
Flow spike volume (ac.ft.)	0.5824	0.7631	0.13

Table 53. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of speckled dace, *Rhinichthys osculus*, in Geomorphic Reach 4, 1993 – 1997.

SUMMMER DISCHARGE ATTRIBUTES	r^2	r	*P*
Summer discharge volume (ac.ft.)	0.0051	0.0717	0.91
Summer discharge mean (cfs)	0.0051	0.0714	0.91
Days >2000 cfs	0.0005	0.0218	0.97
Days >1000 cfs	0.0030	0.0545	0.93
Days <1000 cfs	0.0132	0.1149	0.85
Days < 500 cfs	0.3401	0.5832	0.30
Flow spiked duration (days)	0.0029	0.0539	0.93
Flow spike mean (cfs)	0.0092	0.0957	0.88
Flow spike volume (ac.ft.)	0.0111	0.1053	0.87

Table 54. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of flannelmouth sucker, *Catostomus latipinnis*, Geomorphic Reach 4, San Juan River, 1993 – 1997.

SUMMER DISCHARGE ATTRIBUTE	r^2	r	*P*
Summer discharge volume (ac.ft.)	0.0128	0.1132	0.86
Summer discharge mean (cfs)	0.0129	0.1135	0.86
Days > 2000 cfs	0.0111	0.1052	0.87
Days > 1000 cfs	0.0226	0.1504	0.81
Days < 1000 cfs	0.0193	0.1388	0.82
Days < 500 cfs	0.1471	0.3835	0.52
Flow spike duration (days)	0.0016	0.0399	0.95
Flow spike mean (cfs)	0.0148	0.1216	0.85
Flow spike volume (ac.ft.)	0.0046	0.0679	0.91

Table 55. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of bluehead sucker, *Catostomus discobolus*, Geomorphic Reach 4, San Juan River, 1993 – 1997.

SUMMER DISCHARGE ATTRIBUTE	r^2	r	*P*
Summer discharge volume (ac.ft.)	0.0002	0.0150	0.98
Summer discharge mean (cfs)	0.0002	0.0153	0.98
Days > 2000 cfs	0.0000	0.0000	1.00
Days > 1000 cfs	0.0020	0.0443	0.94
Days < 1000 cfs	0.0019	0.0441	0.94
Days < 500 cfs	0.1973	0.4442	0.45
Flow spike duration (days)	0.0053	0.0729	0.91
Flow spike mean (cfs)	0.0487	0.2207	0.72
Flow spike volume (ac.ft.)	0.0016	0.0397	0.95

< 500 cfs (Figure 74). There were strong negative, and in several instances, significant, relationships between summer discharge and channel catfish abundance (Table 56). The strongest was that with days discharge > 1000 cfs (Figure 74). There was a significant positive relationship between western mosquitofish autumn abundance and days flow < 500 cfs (Figure 74); most other relationships were negative and fairly strong, but not significant (Table 57).

Table 56. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of channel catfish, *Ictalurus punctatus*, Geomorphic Reach 4, San Juan River, 1993 – 1997. An asterisk indicates a significant relationship.

SUMMER DISCHARGE ATTRIBUTE	r^2	r	*p*
Summer discharge volume (ac.ft.)	0.7492	0.8655	0.06
Summer discharge mean (cfs)	0.7490	0.8655	0.06
Days > 2000 cfs	0.7908*	0.8893	0.04
Days > 1000 cfs	0.8786*	0.9394	0.02
Days < 1000 cfs	0.7405	0.8605	0.06
Days < 500 cfs	0.2502	0.5002	0.39
Flow spike duration (days)	0.8268*	0.9093	0.03
Flow spike mean (cfs)	0.6018	0.7757	0.12
Flow spike volume (ac.ft.)	0.7507	0.8664	0.06

Table 57. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of western mosquitofish, *Gambusia affinis*, Geomorphic Reach 4, 1993 – 1997. An asterisk indicates a significant relationship.

SUMMER DISCHARGE ATTRIBUTE	r^2	r	P
Summer discharge volume (ac.ft.)	0.6492	0.8058	0.10
Summer discharge mean (cfs)	0.6491	0.8057	0.10
Days flow > 2000 cfs	0.5797	0.7614	0.14
Days flow > 1000 cfs	0.5174	0.7193	0.17
Days flow < 1000 cfs	0.5869	0.7661	0.13
Days flow < 500 cfs	0.9700*	0.9849	0.01
Flow spike duration 9days)	0.4338	0.6586	0.23
Flow spike mean (cfs)	0.6432	0.8020	0.10
Flow spike volume (ac.ft.)	0.4228	0.6502	0.24

Geomorphic Reach 3

Thirteen species of fish were collected in Reach 3 between 1993 and 1997; five were native and eight were nonnative (Table 58). Total abundance of fishes was greatest in 1995 (8.68 fish/m^2) and least in 1997 (0.79 fish/m^2). Red shiner was the most

Table 58. Number and abundance (number/m^2) of fishes in San Juan River secondary channels in Geomorphic Reach 3 (RM 105 – RM 68) during autumn, 1993 – 1997. Bold-lettered species were used to calculate Kendall's coefficient of concordance.

1993			1994			1995			1996			1997		
SPECIES	N	ABUN	SPECIES	N	ABUN	SPECIES	N	ABUN	SPECIES	N	ABUN	SPECIESs	N	ABUN
CYPLUT	315	1.58	**CYPLUT**	2872	3.63	**CYPLUT**	2444	4.44	**CYPLUT**	960	1.69	**CYPLUT**	527	0.54
RHIOSC	73	0.37	**PIMPRO**	844	1.07	**PIMPRO**	2041	3.71	**PIMPRO**	169	0.30	**RHIOSC**	151	0.15
ICTPUN	67	0.34	**RHIOSC**	262	0.33	**RHIOSC**	203	0.37	**RHIOSC**	27	0.05	**PIMPRO**	47	0.08
CATLAT	31	0.16	**GAMAFF**	230	0.29	**ICTPUN**	26	0.05	**GAMAFF**	27	0.05	**ICTPUN**	23	0.04
PIMPRO	27	0.14	**CATLAT**	122	0.15	**GAMAFF**	20	0.04	**CATLAT**	21	0.04	PTYLUC	13	0.02
CYPCAR	4	0.02	**ICTPUN**	80	0.10	**FUNZEB**	17	0.03	**ICTPUN**	19	0.03	**CATLAT**	10	0.02
FUNZEB	2	0.01	**FUNZEB**	8	0.01	**CATDIS**	10	0.02	**CATDIS**	7	0.01	GILROB	4	0.01
			CATDIS	6	0.01	**CATLAT**	7	0.01	**FUNZEB**	5	0.01	**CATDIS**	2	<0.01
			CYPCAR	2	<0.01	**CYPCAR**	4	0.01				**CYPCAR**	1	<0.01
			AMEMEL	2	<0.01	AMEMEL	1	<0.01				**FUNZEB**	1	<0.01
						LEPCYA	1	<0.01				**GAMAFF**	1	<0.01
TOTAL N	519			4428			4774			1235			780	
AREA	200			792			550			568			983	
ABUN	2.595			5.591			8.680			2.174			0.794	
H	1.224			1.117			0.943			0.820			1.048	

abundant species each year of the study. Its abundance and that of fathead minnow (the second- or third-most abundant species each year) increased from 1993 through 1995 and then declined to their Reach 3 lows in 1997. The abundance of speckled dace, the second- or third-most abundant species, was fairly constant from 1993 through 1995, decreased to its reach low in 1996, and then increased in 1997. Flannelmouth sucker abundance was low throughout the study, and was lowest in 1997. Bluehead sucker was not captured in Reach 3 in 1993, but was present in subsequent years, albeit in low numbers. Channel catfish abundance declined from 1993 through 1996 and increased slightly in 1997. Colorado pikeminnow and roundtail chub were collected in 1997. There was high concordance of species abundance rank across years in Reach 3 (Friedman's χ^2 = 31.56, $p < 0.001$, W = 0.7890). Assemblage diversity (H) decreased as total abundance increased from 1993 through 1995 (Figure 75). Diversity was lowest in 1996 and slightly higher in 1997, when total abundance was lowest. Fish abundance in Reach 3 was not related to discharge at time of sampling (r^2 = 0.112, $p < 0.580$).

Unlike in Reaches 5 and 4, the coefficient of variation for species abundance in Reach 3 did not increase as abundance declined (Figure 76). Fathead minnow, a common species, and western mosquitofish, an uncommon species, had the highest CVs.

As a proportion of the total collection, native fishes declined from about 20 to 4.5% from 1993 through 1996 (Figure 77). In 1997, native fishes were about 21 % of the collection. Red shiner was 60% or more of each year's collection in all years except 1995 when it was 51%. Fathead minnow relative abundance peaked at 43% in 1995. Speckled dace steadily declined in relative abundance from 1993 through 1996, but increased to its highest proportion in 1997.

Overall, abundance of fish species in Reach 3 was not related to any attribute of summer discharge. The strongest relationship between red shiner abundance and summer discharge attribute was that with spike duration (Table 59 and Figure 78). Fathead

Table 59. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of red shiner, *Cyprinella lutrensis*, Geomorphic Reach 3, 1993 – 1997.

SUMMER DISCHARGE ATTRIBUTE	r^2	r	*p*
Summer discharge volume (ac.ft.)	0.0511	0.2261	0.72
Summer discharge mean (cfs)	0.0511	0.2260	0.72
Days > 2000 cfs	0.1940	0.4404	0.46
Days > 1000 cfs	0.0695	0.2635	0.67
Days < 1000 cfs	0.0101	0.1007	0.87
Days < 500 cfs	0.0002	0.0149	0.98
Flow spike duration (days)	0.4562	0.6754	0.21
Flow spike mean (cfs)	0.3524	0.5936	029
Flow spike volume (ac.ft.)	0.4516	0.6720	0.21
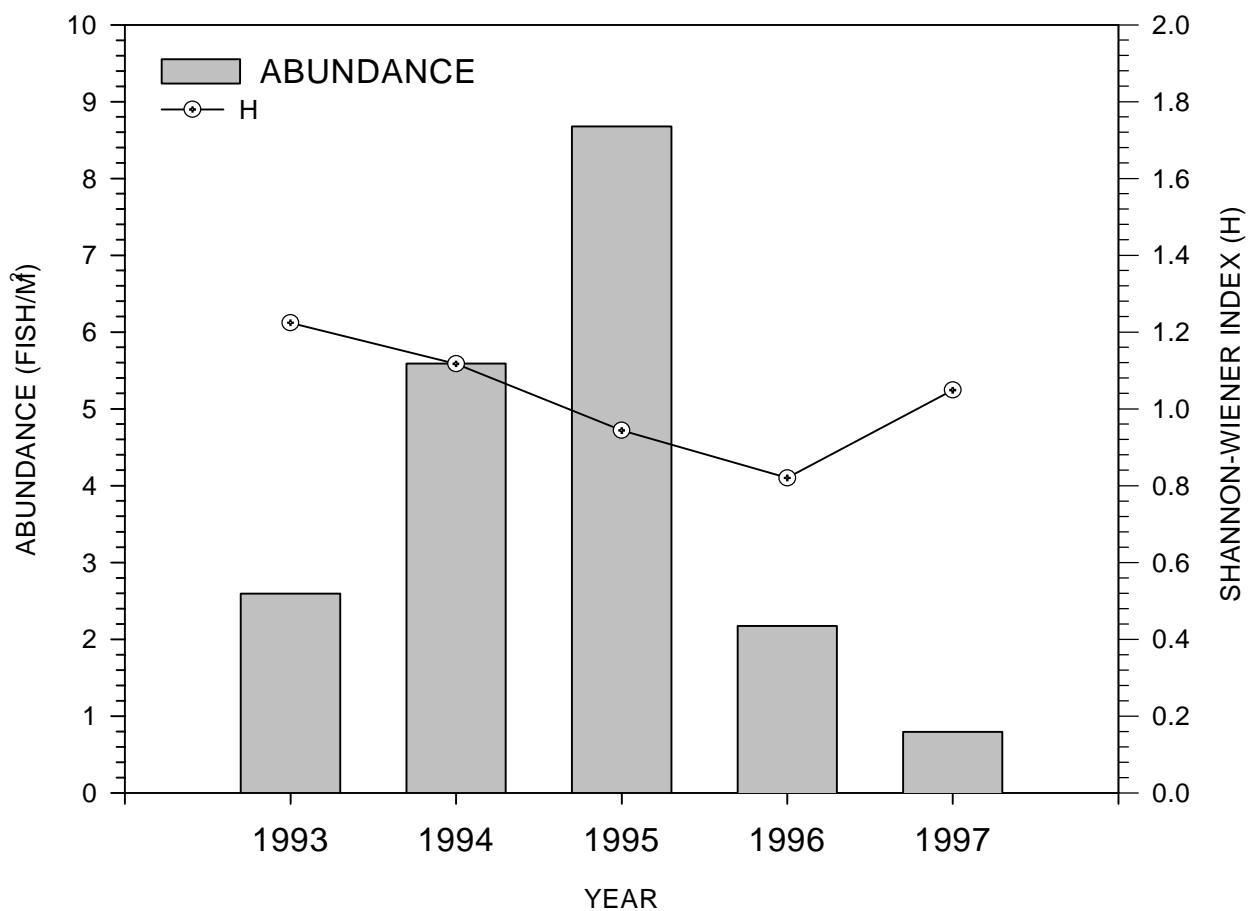
Figure 74. Abundance of fishes and Shannon-Wiener Diversity Index values for fish assemblages during autumn in Geomorphic Reach 3, San Juan River, 1993 - 1997.
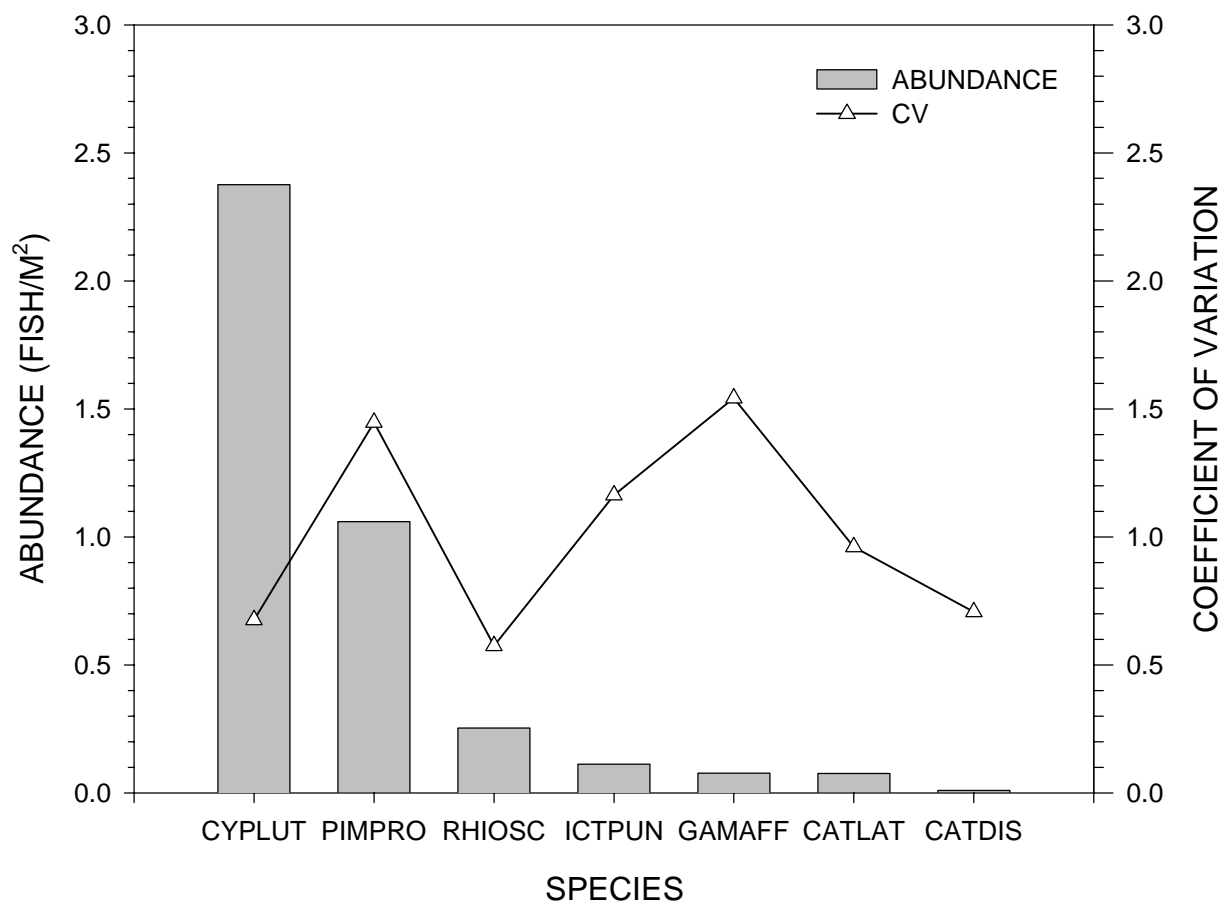
Figure 75. Mean abundance (1993 - 1997) and coefficient of variation (CV)
of abundance of fish species commonly collected during autumn in
Geomorphic Reach 3, San Juan River, 1993 - 1997.
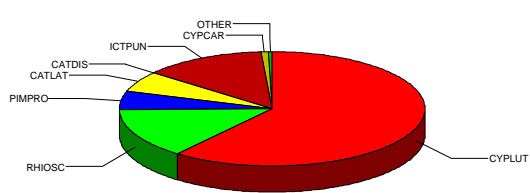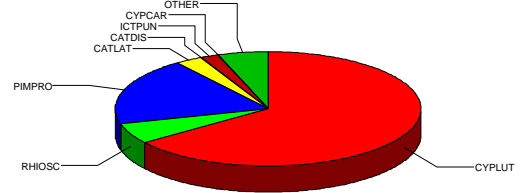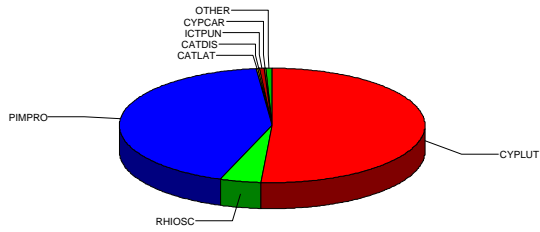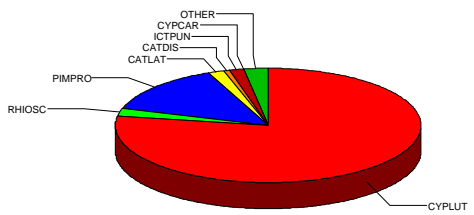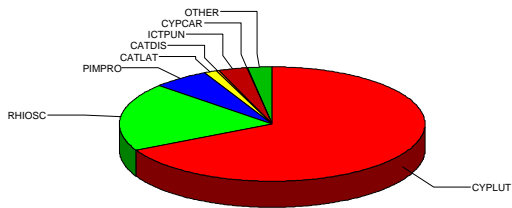
Figure 76. Relative abundance of commonly collected fishes during autumn in Geomorphic Reach 3, San Juan River, 1993 – 1997.

minnow abundance was not related to any flow attribute (Table 60); Figure 77 illustrates the typical relationship. With the exception of days flow < 500 cfs, there was no relationship between summer discharge and speckled dace abundance (Table 61); days flow < 500 cfs was weakly negative (Figure 77). Abundance of neither sucker species was related to any flow attribute (Tables 62 and 63). Figure 77 illustrates the absence of relationships. Channel catfish was negatively, but not significantly, related to days flow < 1000 cfs (Figure 77), but was not related to other flow attributes (Table 64). Abundance of western mosquitofish was not related to any flow attribute (Table 65 and Figure 77).

Table 60. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of fathead minnow, *Pimephales promelas*, Geomorphic Reach 3, 1993 – 1997.

SUMMER DISCHARGE ATTRIBUTE	r^2	r	*p*
Summer discharge volume (ac.ft.)	0.0348	0.1867	0.76
Summer discharge mean (cfs)	0.0348	0.1866	0.76
Days > 2000 cfs	0.0032	0.0565	0.93
Days > 1000 cfs	0.0430	0.2073	0.74
Days < 1000 cfs	0.1200	0.3464	0.57
Days < 500 cfs	0.0752	0.2743	0.66
Flow spike duration (days)	0.0917	0.3028	0.62
Flow spike mean (cfs)	0.0907	0.3012	0.62
Flow spike volume (ac.ft.)	0.1134	0.3368	0.58

Table 61. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of speckled dace, *Rhinichthys osculus*, Geomorphic Reach 3, 1993 – 1997.

SUMMER DISCHARGE ATTRIBUTE	r^2	r	*p*
Summer discharge volume (ac.ft.)	0.0138	0.1173	0.85
Summer discharge mean (cfs)	0.0138	0.1173	0.85
Days > 2000 cfs	0.0019	0.0431	0.95
Days > 1000 cfs	0.0001	0.0003	1.00
Days < 1000 cfs	0.0243	0.1560	0.80
Days < 500 cfs	0.3973	0.6304	0.25
Flow spike duration (days)	0.0588	0.2425	0.69
Flow spike mean (cfs)	0.0001	0.0073	0.99
Flow spike volume (ac.ft.)	0.0567	0.2381	0.70
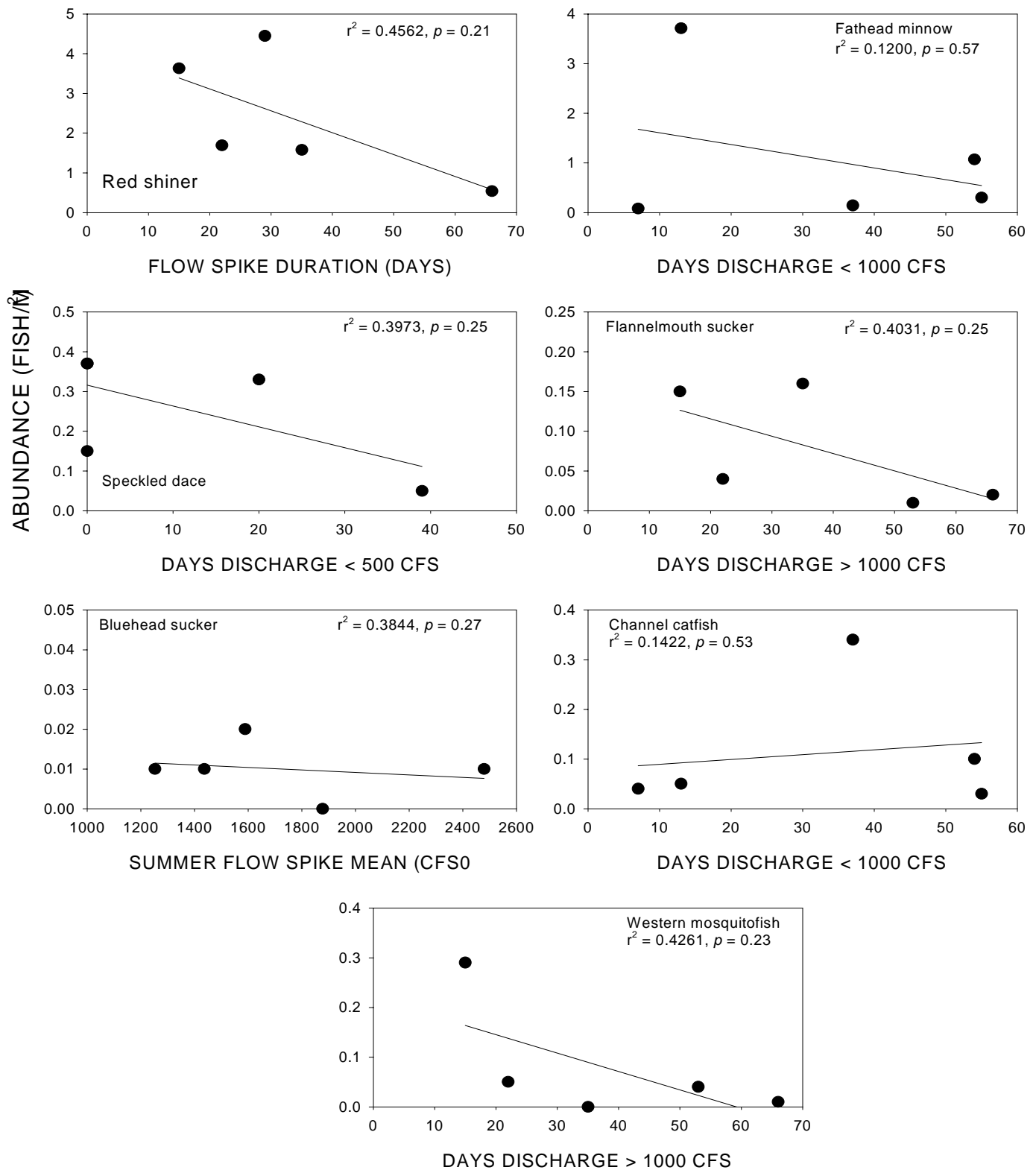
Figure 77. Autumn abundance of fishes in Geomorphic Reach 3 versus attributes of summer discharge, San Juan River, 1993 - 1997.

Table 62. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of flannelmouth sucker, *Catostomus latipinnis*, Geomorphic Reach 3, San Juan River, 1993 – 1997.

SUMMER DISCHARGE ATTRIBUTE	r^2	r	*p*
Summer discharge volume (ac.ft)	0.2522	0.5022	0.39
Summer discharge mean (cfs)	0.2522	0.5022	0.39
Days flow > 2000 cfs	0.1984	0.4454	0.45
Days flow > 1000 cfs	0.4031	0.6349	0.25
Days flow < 1000 cfs	0.3490	0.5908	0.29
Days flow < 500 cfs	0.0002	0.0149	0.98
Flow spike duration (days)	0.1671	0.4087	0.49
Flow spike mean (cfs)	0.0313	0.1769	0.78
Flow spike volume (ac.ft)	0.1297	0.3601	0.55

Table 63. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of bluehead sucker, *Catostomus discobolus* Geomorphic Reach 3, San Juan River, 1993 – 1997.

SUMMER DISCHARGE ATTRIBUTES	r^2	r	*p*
Summer discharge volume (ac.ft)	0.0252	0.1587	0.80
Summer discharge mean (cfs)	0.0252	0.1587	0.80
Days flow > 2000 cfs	0.1322	0.3636	0.55
Days flow > 1000 cfs	0.0103	0.1016	0.87
Days flow < 1000 cfs	0.0001	0.0057	0.99
Days flow < 500 cfs	0.0348	0.1865	0.76
Flow spike duration (days)	0.3036	0.5511	0.34
Flow spike mean (cfs)	0.3844	0.6200	0.27
Flow spike volume (ac.ft)	0.3324	0.5765	0.31

Table 64. Results of linear regression analysis of relationship between summer discharge attributes and autumn secondary channel abundance of channel catfish, *Ictalurus punctatus*, Geomorphic Reach 3, San Juan River, 1993 – 1997.

SUMMER DISCHARGE ATTRIBUTES	r^2	r	*p*
Summer discharge volume (ac.ft)	0.0169	0.1300	0.84
Summer discharge mean (cfs)	0.0170	0.1302	0.84
Days flow > 2000 cfs	0.0131	0.1143	0.86
Days flow > 1000 cfs	0.0341	0.1846	0.77
Days flow < 1000 cfs	0.7405	0.8605	0.06
Days flow < 500 cfs	0.1422	0.3771	0.53
Flow spike duration (days)	0.0029	0.0540	0.93
Flow spike mean (cfs)	0.0156	0.1251	0.84
Flow spike volume (ac.ft)	0.0052	0.0720	0.91

Table 65. Results of linear regression analysis of relationship between summer discharge
  attributes and autumn secondary channel abundance of western mosquitofish, *Gambusis
affinis*, Geomorphic Reach 3, San Juan River, 1993 – 1997

SUMMER DISCHARGE ATTRIBUTE	r^2	r	*p*
Summer discharge volume (ac.ft)	0.2557	0.5056	0.39
Summer discharge mean (cfs)	0.2554	0.5053	0.39
Days > 2000 cfs	0.2540	0.5040	0.39
Days > 1000 cfs	0.4261	0.6528	0.23
Days < 1000 cfs	0.3138	0.5610	0.33
Days , 500 cfs	0.1398	0.3739	0.54
Flow spike duration (days)	0.3685	0.6071	0.28
Flow spike mean (cfs)	0.2114	0.4598	0.44
Flow spike volume (ac.ft)	0.2608	0.5107	0.38

Among Reach Comparisons

Abundance of fishes in secondary channels of each Geomorphic Reach varied
considerably from year to year. In Reach 5, abundance was comparatively high in 1993,
declined through 1995, increased in 1996, and declined again in 1997 (Figure 78).
Abundance in Reach 4 did not change greatly from 1993 through 1996, but dropped in
1997. Abundance in Reach 3 increased from 1993 through 1995 and then declined
through 1997. Despite these changes, differences were not significant for either across
years-within reach (F = 1.47, *p* < 0.28) or within-across reaches (F = 0.55, *p* < 0.59)
comparisons. Mean abundance (all years) was highest (4.08 fish/m^2) in Reach 5 and
lowest (2.63 fish/m^2) in Reach 4; that of Reach 3 was 3.97 fish/m^2. Coefficients of
variation for abundance were moderately high (59 and 51 %) in Reaches 5 and 4 and high
(80 %) in Reach 3.

Within each reach, Shannon-Wiener Diversity Index values did not change
significantly from year to year (F = 0.84, *p* < 0.53). Diversity was highest in Reach 5 in
all years and usually lowest in Reach 3 (Figure 84). Among reach comparisons yielded
significant differences in Diversity Index values (F = 9.39, *p* < 0.004). Post hoc tests
indicated that diversity for Reach 5 was significantly greater than that of Reaches 4 and 3.
Mean assemblage diversity was 1.4367, 1.1361, and 1.0309 in Reaches 5, 4, and 3,
respectively. The CV for diversity was low (< 15 %) in all reaches.

Colorado Pikeminnow Captures

During 1997 autumn inventories, 206 specimens of Colorado squawfish were
captured in secondary channels. Most, and likely all, individuals were those released as
part of the studies being conducted by Utah Division of Wildlife Resources on survival of
young Colorado squawfish. Captures were primarily in the vicinity of RM 150 to RM
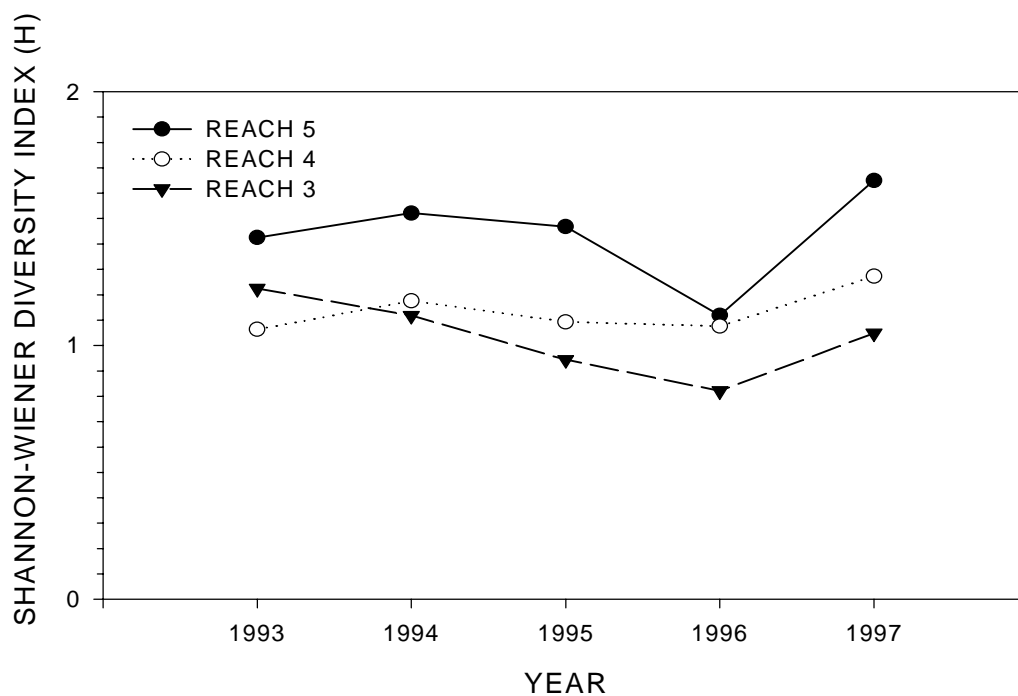
Figure 78. Shannon-Wiener Diversity Index (H) values of fish assemblages
in San Juan River secondary channels, 1993 - 1997.
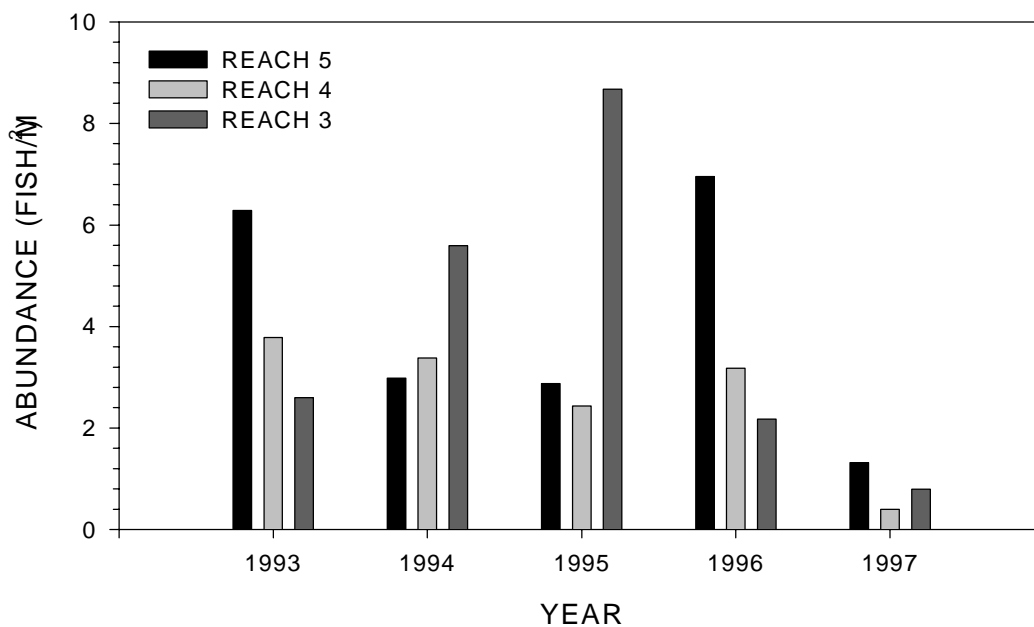
Figure 79. Abundance of fishes(fish/m^2) in San Juan River secondary
channels, 1993 - 1997.

148 (n = 29), RM 131 to RM 138 (n = 147), and RM 103 (n = 8). Single individuals were collected upstream, between, and downstream of these concentrations (Table 66). Most specimens were captured in low-velocity habitats such as backwaters and pools, but some were captured in habitats having comparatively rapid velocity water (e.g., runs and riffles). A backwater pool in a secondary channel at RM 132.2 to RM 131.3 yielded 130 specimens.

Table 66. San Juan River secondary channel captures of Colorado squawfish, *Ptychocheilus lucius*, during autumn inventories, 1993 – 1997. Parenthetic numbers with TL indicate number of specimens captured in a mesohabitat if more than one.

DATE	RM	TL (mm)	HABITAT
30 SEP 97	155.5 – 155.2	50	--
30 SEP 97	155.5 – 155.2	53	--
30 SEP 97	155.5 – 155.2	ca. 50	--
30 SEP 97	155.5 – 155.2	ca. 50	--
30 SEP 97	150.3 – 149.9	ca. 50 (4)	EDDY POOL
30 SEP 97	150.3 – 149.9	ca. 50 (10)	BACKWATER
30 SEP 97	148.5 – 148.3	ca. 50 (4)	SHORE RUN
30 SEP 97	148.5 – 148.3	ca. 50 (7)	SHORE RUN
30 SEP 97	148.5 – 148.3	ca. 50	SHORE RUN
30 SEP 97	148.5 – 148.3	ca. 50 (3)	MID-CHANNEL RUN
1 OCT 97	144.0 – 143.8	ca. 50	POOL RUN
1 OCT 97	143.1 – 142.9	ca. 50	DEBRIS POOL-RUN
1 OCT 97	143.1 – 142.9	ca. 50	SHOAL-RUN
1 OCT 97	143.1 – 142.9	ca. 50	RIFFLE
1 OCT 97	141.4 – 141.05	ca. 50	SLACKWATER
1 OCT 97	140.6 – 140.0	ca. 50	EMBAYMENT
1 OCT 97	138.1 – 137.9	ca. 50 (14)	POOL
1 OCT 97	136.6 – 134.6	ca. 50 (3)	RIFFLE
2 OCT 97	132.2 – 131.3	ca. 50 (130)	BACKWATER POOL
2 OCT 97	130.9 – 130.75	ca. 50	MID CHANNEL RUN
2 OCT 97	129.05 – 128.9	ca. 50	RUN
2 OCT 97	128.7 – 128.1	ca. 50 (3)	SHOAL RUN
2 OCT 97	127.7 – 127.6	ca. 50	RUN-CHUTE
2 OCT 97	127.2 – 126.6	ca. 50	RIFFLE EDDY
2 OCT 97	127.2 – 126.6	ca. 50	EDDY
3 OCT 97	117.5 – 117.2	ca. 50	POOL
5 OCT 97	103.4 – 103.2	ca. 50 (2)	DEBRIS POOL
5 OCT 97	103.4 – 103.2	ca. 50 (2)	POOL
5 OCT 97	103.4 – 103.2	ca. 50 (2)	SHOAL
5 OCT 97	103.4 – 103.2	ca. 50 (2)	DEBRIS POOL
5 OCT 97	99.05 – 98.6	ca. 50	POOL
6 OCT 97	87.7 – 87.5	ca. 50	POOL
6 OCT 97	87.7 – 87.5	ca. 50	DEBRIS POOL

FISH ASSEMBLAGES OF SAN JUAN RIVER

SECONDARY CHANNELS

SEASONAL COMPARISONS

1993 – 1997

INTRODUCTION

During spring runoff (1 March through 1 July), San Juan River secondary channels provided habitat for both large- and small-bodied fish species. Most individuals captured during spring inventories were sub-adults and adults of large-bodied fish species, particularly flannelmouth sucker, bluehead sucker, common carp, and channel catfish. Speckled dace, red shiner, fathead minnow, common small-bodied fishes, were captured but never were more than a small proportion of spring samples. Flow volume (typically > 4000 cfs) and method of specimen collection (raft-mounted electrofishing) precluded efficient sampling of small-bodied fishes; thus these species were likely under-represented in spring inventories. Nonetheless, comparisons of primary and secondary channel spring runoff collections indicted that the fish assemblages of both habitats were similar in most respects. Reproduction by most native fishes, particularly large-bodied species, occurred during spring runoff, and its recession (variable among years, but normally late-June through mid- to late July).

During summer secondary channel inventories, discharge of the San Juan River was normally less than 1200 cfs and surface water in many secondary channels was limited to short flowing reaches and isolated pools; few had continuous surface flow for their entire lengths. Under such conditions, few large-bodied specimens were collected, but small-bodied fishes were common. Red shiner, fathead minnow, speckled dace, and western mosquitofish were usually the most common fishes found, especially Age-0 individuals. Spawning of red shiner and fathead minnow peaked during summer low-flow periods, but speckled dace spawning was largely completed by early July. Age-0 individuals of flannelmouth sucker, bluehead sucker, and channel catfish were frequently found in secondary channels but were rarely abundant.

Autumn inventories were conducted after all spawning activity when flows were, in average, about the same as during summer but less variable. Available habitat in secondary channels in autumn was not substantially different from that available in summer. All species (except incidental species) collected in summer were also collected in autumn.

Objectives of the Secondary Channel Ichthyological Inventory were:

1) Characterize the type of secondary channels in the San Juan River;
2) Characterize the faunal assemblages of secondary channels;
3) Determine seasonal use patterns of secondary channels by target species; and

4)   Relate habitat use and availability of secondary channels to flow levels.

This chapter compares the summer and autumn faunal assemblages of San Juan River secondary channels and thus addresses Objectives 2 and 4 of the Secondary Channel Studies.

METHODS

Summer and autumn comparisons were limited to total abundance and abundance of species commonly collected in both seasons. Specific seasonal comparisons (by Geomorphic Reach) included red shiner, fathead minnow, speckled dace, flannelmouth sucker, bluehead sucker, and western mosquitofish. The statistical methods used were the same as those for within season analyses. In addition, repeated measures ANOVA was used to evaluate differences in total and species abundances between seasons (reaches combined) and among reaches (years combined).

RESULTS

The abundance of fishes in secondary channels in each reach was usually greater, often substantially, in summer than autumn (Figure 81). In Reach 5, total abundance during summer declined from a high of 25.2 in 1993 to a low of 1.26 fish/m^2 in 1997 (Reach mean = 10.67). In contrast, total abundance during autumn was comparatively constant during the study (Reach mean = 4.08). In Reach 4, summer abundance (Reach mean = 10.41) also varied considerably from year to year, but autumn abundance was fairly constant across years, except in 1997 (mean = 2.64). The year to year total abundance changes (Reach mean = 5.89) in Reach 3 mirrored, but were lower than, those found in Reach 4. Differences in the CV of summer and autumn abundance in Reaches 5 and 4 reflected the relative inconstancy of abundance during summer in these reaches and its relative constancy in autumn (Table 67). The CVs for summer and autumn in Reach 3 were almost the same, and high.

Repeated-measures ANOVA yielded significant differences for between season (Figure 82: F = 11.245, $p < 0.02$; Reaches combined) and among years (F = 8.605, $p < 0.001$) comparisons of total abundance. Reach comparisons (Figure 83; seasons combined) did not yield significant differences in total abundance (F = 0.172, $p < 0.85$), but year differences were significant (F = 4.433, $p < 0.02$).

Repeated-measures ANOVA was also applied to an assessment of species-specific differences in abundance. For red shiner, seasonal differences (Figure 84; reaches combined) were not significant (F = 2.445, $p < 0.193$) , but differences among years were (F = 5.53, $p < 0.006$). When seasons were combined (Figure 85), neither reach (F = 0.393, $p < 0.705$) nor year (F = 3.189, $p < 0.053$) differences were significant.
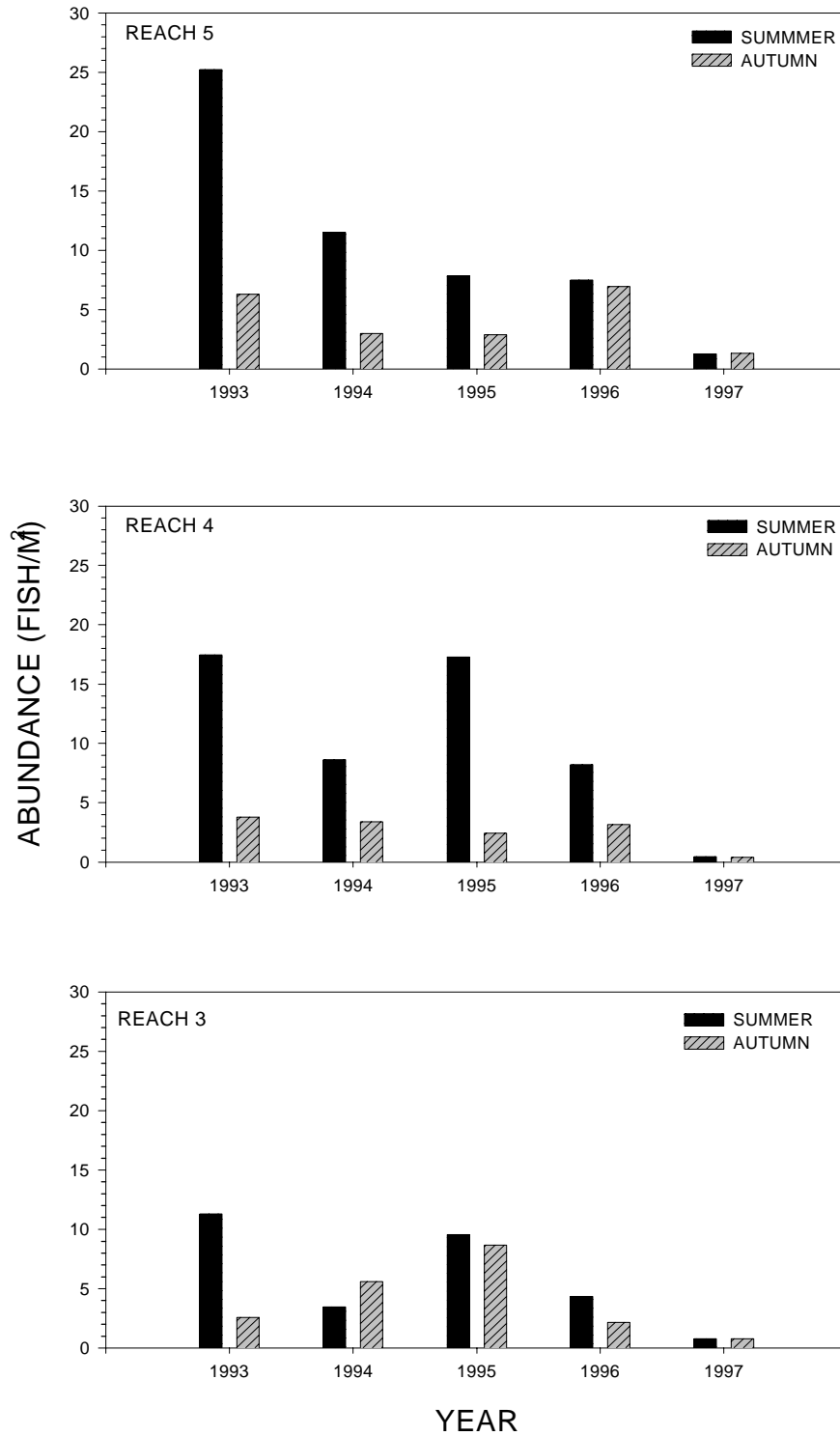
Figure 80. Summer and autumn abundance of fishes in San Juan River
secondary channels, Geomorphic Reaches 5, 4, and
3, 1993 - 1997.

Table 67. Mean abundance (fish/m^2), standard deviation (SD), and coefficient of variation (CV, expressed as %) of fish abundance in San Juan River secondary channels during summer and autumn, 1993 – 1997.

	REACH 5		REACH 4		REACH 3	
	SUMMER	AUTUMN	SUMMER	AUTUMN	SUMMER	AUTUMN
TOTAL						
MEAN	10.666	4.082	10.409	2.635	5.891	3.967
SD	8.930	2.420	7.149	1.344	4.387	3.163
CV	83.7	59.3	68.9	51.0	74.5	79.7
CYPLUT						
MEAN	3.390	1.648	6.056	1.578	1.938	2.376
SD	4.047	1.104	4.970	0.820	1.584	1.605
CV	130.0	67.0	82.1	52.0	95.7	67.6
PIMPRO						
MEAN	3.252	0.970	1.944	0.416	1.492	1.060
SD	2.974	0.728	1.490	0.415	1.493	1.534
CV	91.5	75.0	76.6	99.7	100.0	144.7
RHIOSC						
MEAN	1.928	0.690	1.620	0.394	1.568	0.254
SD	1.696	0.494	1.310	0.395	1.719	0.146
CV	88.0	71.6	80.9	100.2	109.6	57.4
CATLAT						
MEAN	0.196	0.086	0.132	0.044	0.246	0.076
SD	0.169	0.089	0.156	0.060	0.259	0.073
CV	86.0	103.2	118.1	136.0	105.2	96.1
CATDIS						
MEAN	1.218	0.080	0.284	0.030	0.204	0.010
SD	1.521	0.116	0.476	0.051	0.276	0.007
CV	124.9	194.4	167.7	168.3	135.3	70.7
GAMAFF						
MEAN	0.478	0.298	0.060	0.124	0.140	0.078
SD	0.649	0.361	0.085	0.141	0.263	0.120
CV	135.7	121.2	142.4	114.0	188.0	154.2

With reaches combined (Figure 86), abundance of fathead minnow was not significantly different seasonally (F = 6.267, $p < 0.067$) or among years (F = 1.634, $p < 0.214$). Nor were significant differences in abundance found with seasons combined (Figure 87); among-reach F = 0.407, $p < 0.698$ and among-year F = 2.692, $p < 0.082$. Differences in abundance of speckled dace were significant for three of four comparisons. Both
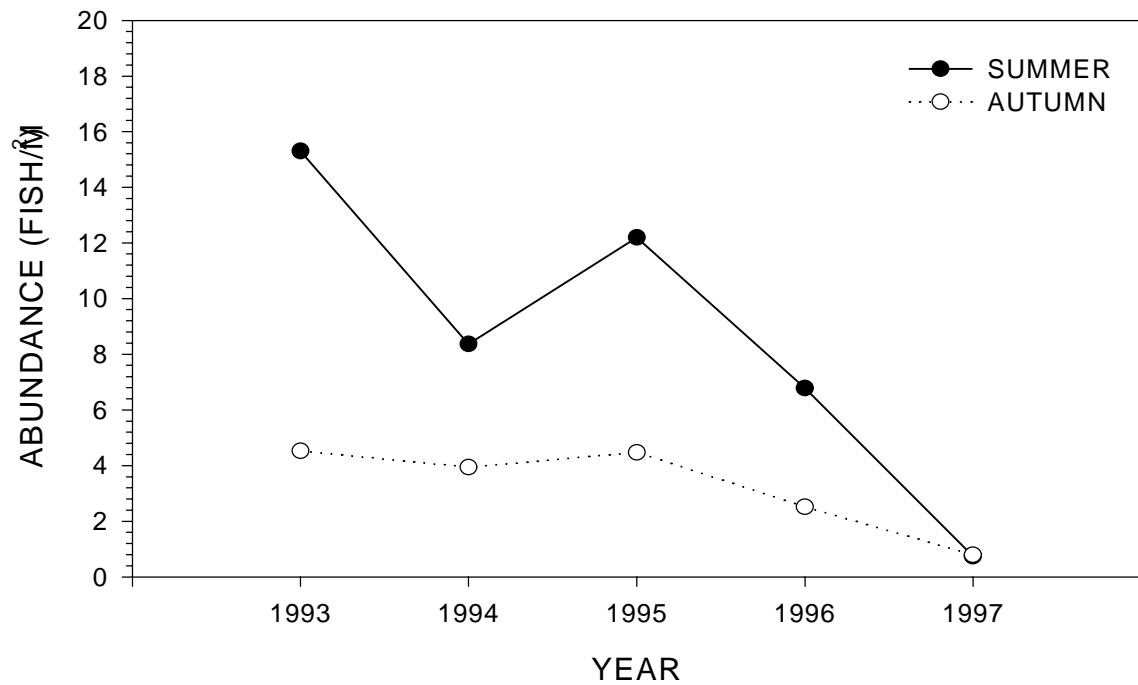
Figure 81. Summer and autumn abundance (fish/m^2, reaches combined) of fishes in San Juan River secondary channels, 1993 - 1997.
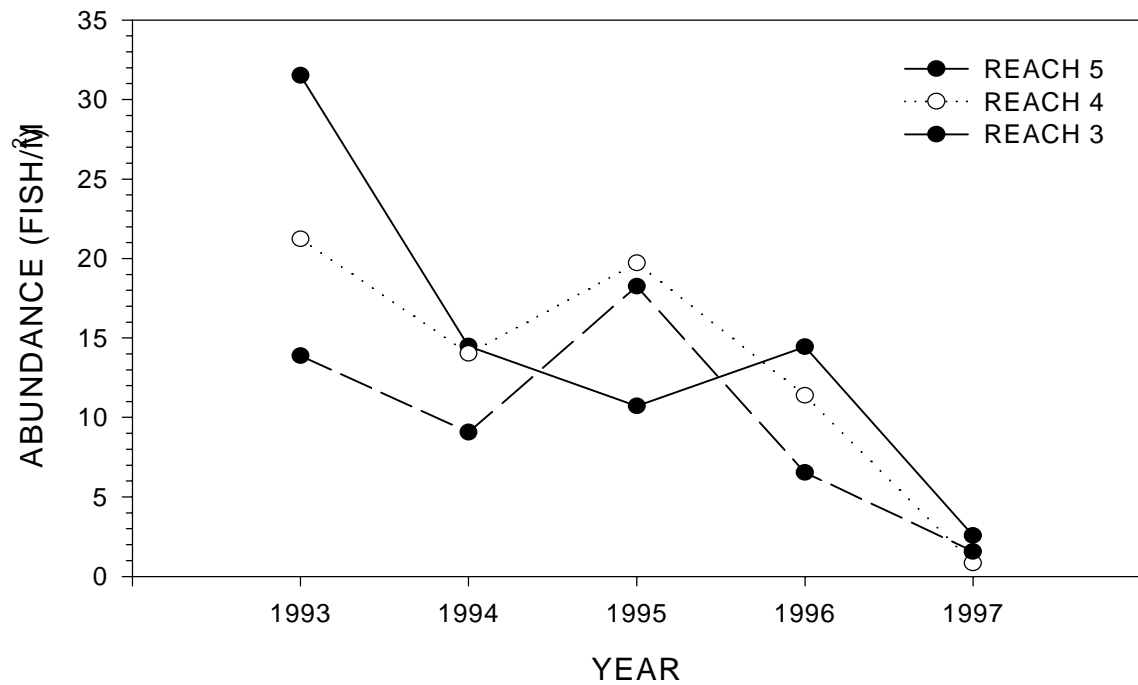
Figure 82. Total reach abundance (fish/m^2, seasons combined) of fishes in San Juan River secondary channels, 1993 - 1997.
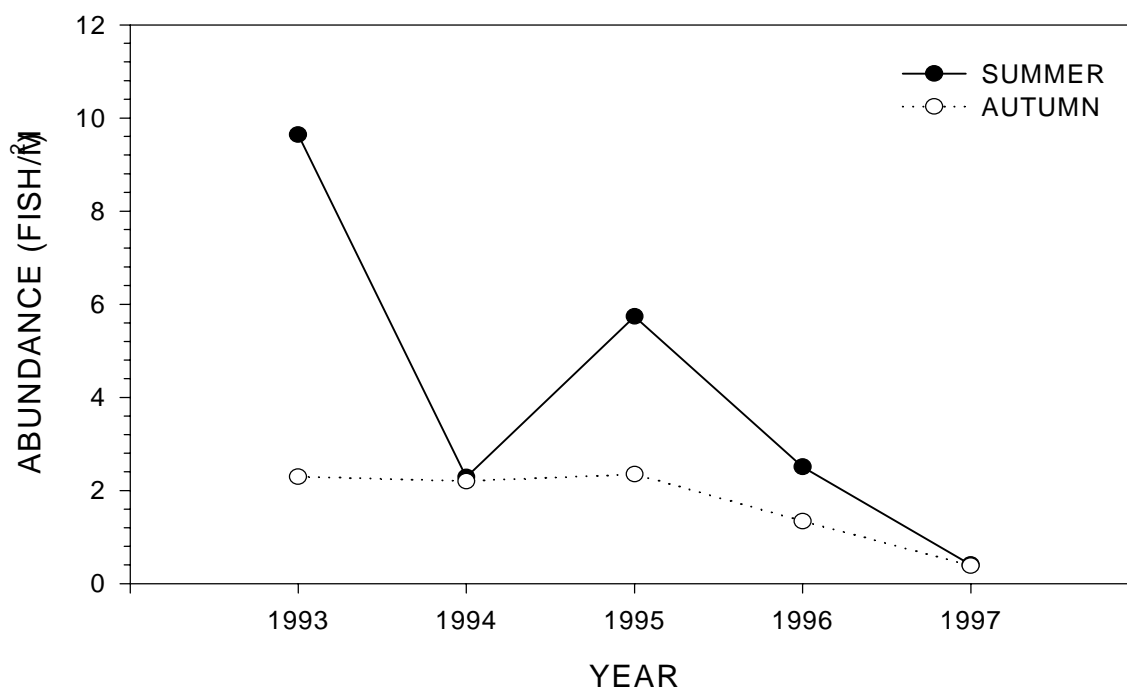
Figure 83. Summer and autumn abundance (fish/m^2, reaches combined) of red shiner, *Cypinella lutrensis*, in San Juan River secondary channels, 1993 - 1997.
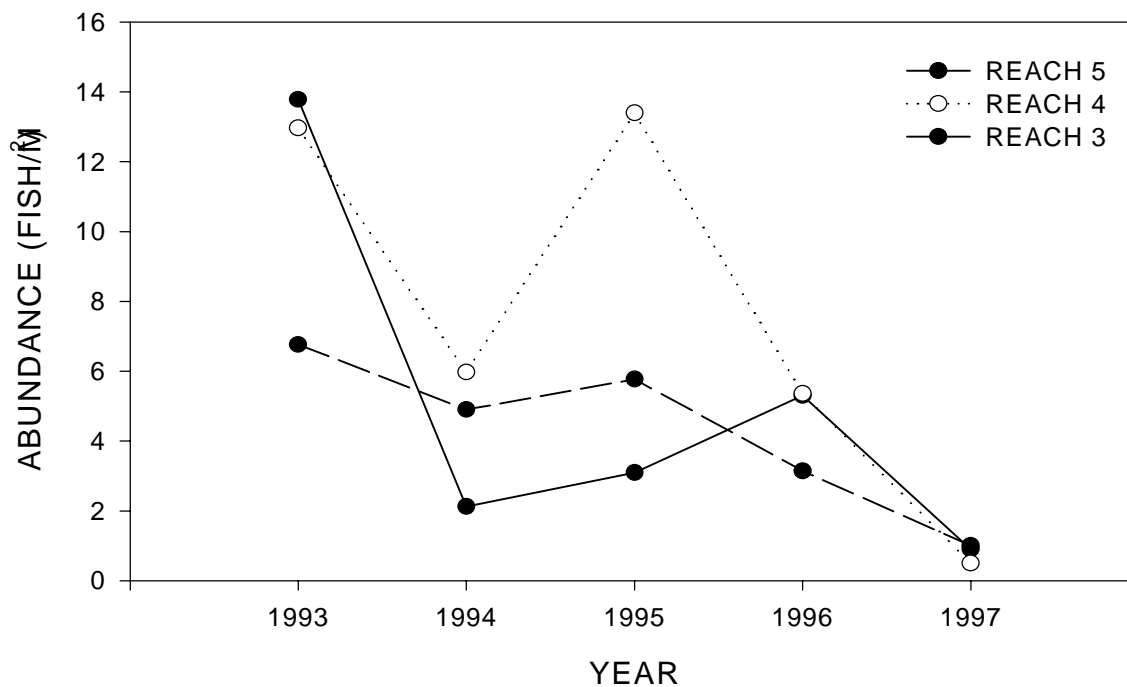
Figue 84. Reach abundance (fish/m^2, seasons combined) of red shiner, *Cyprinella lutrensis*, in San Juan River secondary channels, 1993 - 1997.
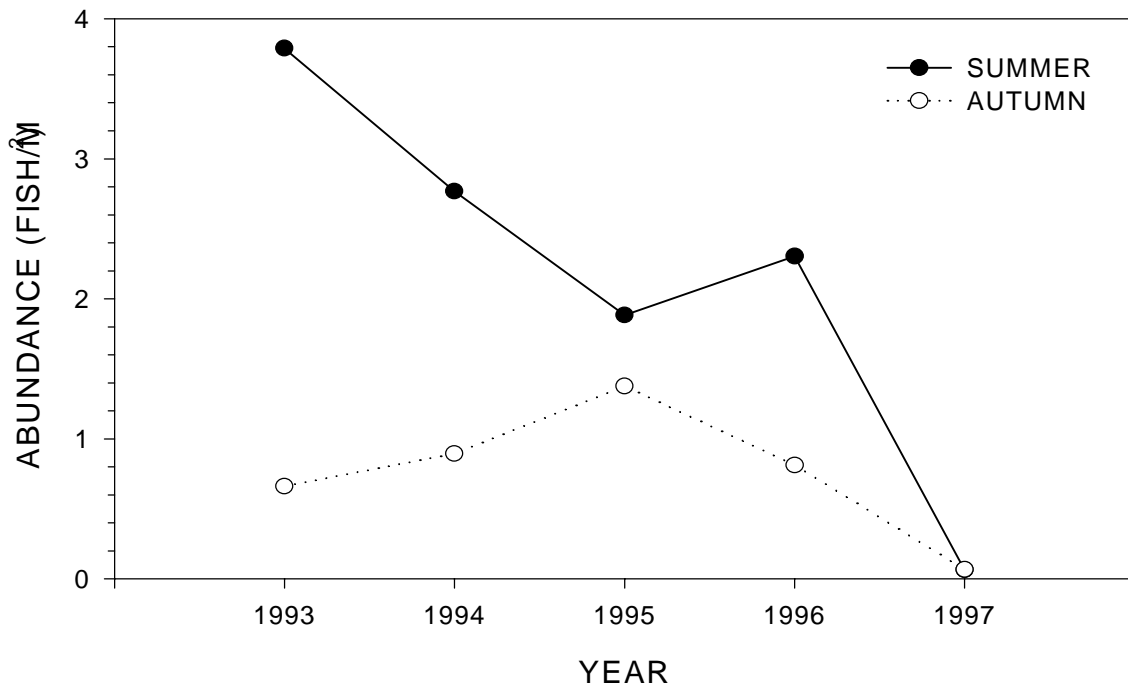
Figure 85. Summer and autumn abundance (fish/m^2, reaches combined) of fathead minnow, *Pimephales promelas*, in San Juan River secondary channels, 1993 - 1997.
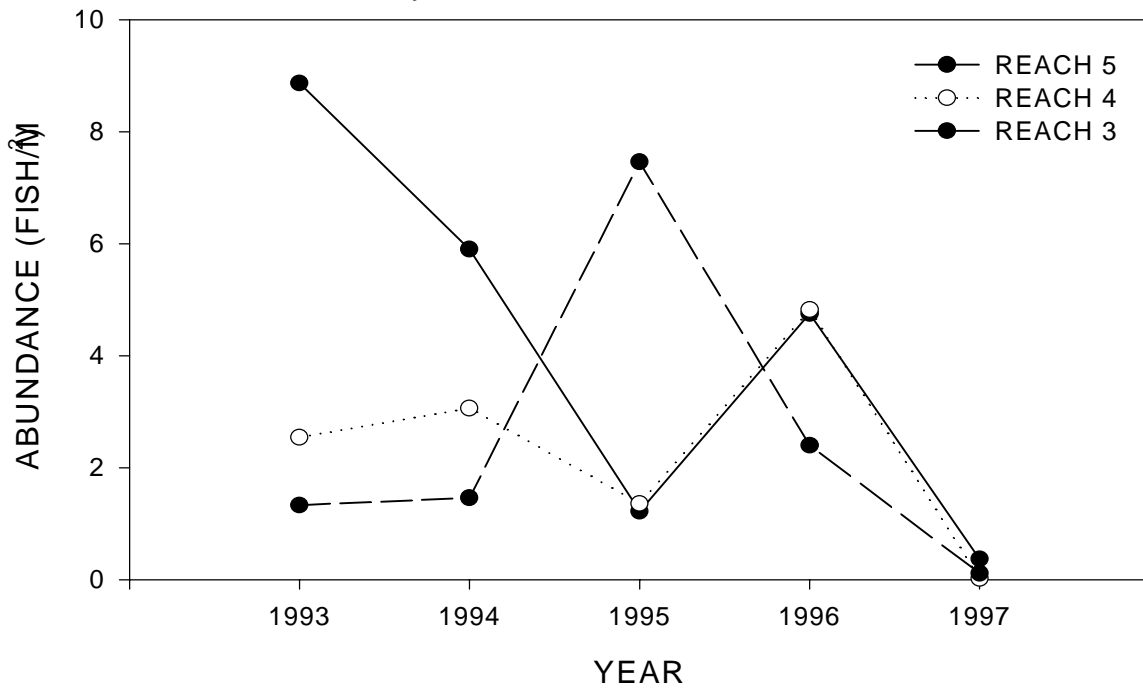
Figure 86. Reach abundance (fish/m^2, seasons combined) of fathead minnow, *Pimephales promelas*, in San Juan River secondary channels 1993 - 1997.

between-season (Figure 88; F = 54.43, $p < 0.002$) and among years (F = 3.658, $p < 0.004$) differences were significant with reaches combined. With seasons combined (Figure 89) among-year (F = 4.759, $p < 0.016$) differences were significant but among-reach differences (F = 0.109, $p < 0.90$) were not. Results for flannelmouth sucker were similar to those found for speckled dace. With reaches combined (Figure 90) seasonal and year differences were significant (F = 12.048, $p < 0.026$ and F = 28.887, $p < 0.001$), but only year differences were significant (F = 9.509, $p < 0.001$) when seasons were combined (Figure 91). The only significant difference found for bluehead sucker comparisons was that for year (F = 3.437, $p < 0.032$), with reaches combined (Figure 92). The nonsignificant comparisons were season (F = 2.627, $p < 0.18$; reaches combined) and reach (F = 0.771, $p < 0.537$) and year (F = 2.181, $p < 0.133$) when seasons were combined (Figure 93). With reaches combined (Figure 94), differences in western mosquitofish abundance were significant for year comparisons (F = 6.279, $p < 0.003$) but not for season (F = 0.168, $p < 0.702$). The results obtained when seasons were combined (Figure 95) were similar; reach differences were not significant (F = 8.217, $p < 0.061$) but years were (F = 12.200, $p < 0.001$).

Total summer abundance was not a good predictor of total autumn abundance (Figure 96). However, the summer abundance of several species was a fairly good predictor of their autumn abundance. Summer abundance of fathead minnow, speckled dace, flannelmouth sucker, bluehead sucker, and western mosquitofish were predictive of their autumn abundance (Figures 97, 98, and 99). The summer abundance of red shiner and channel catfish was not a good predictor of their autumn abundance (Figures 101 and 103).
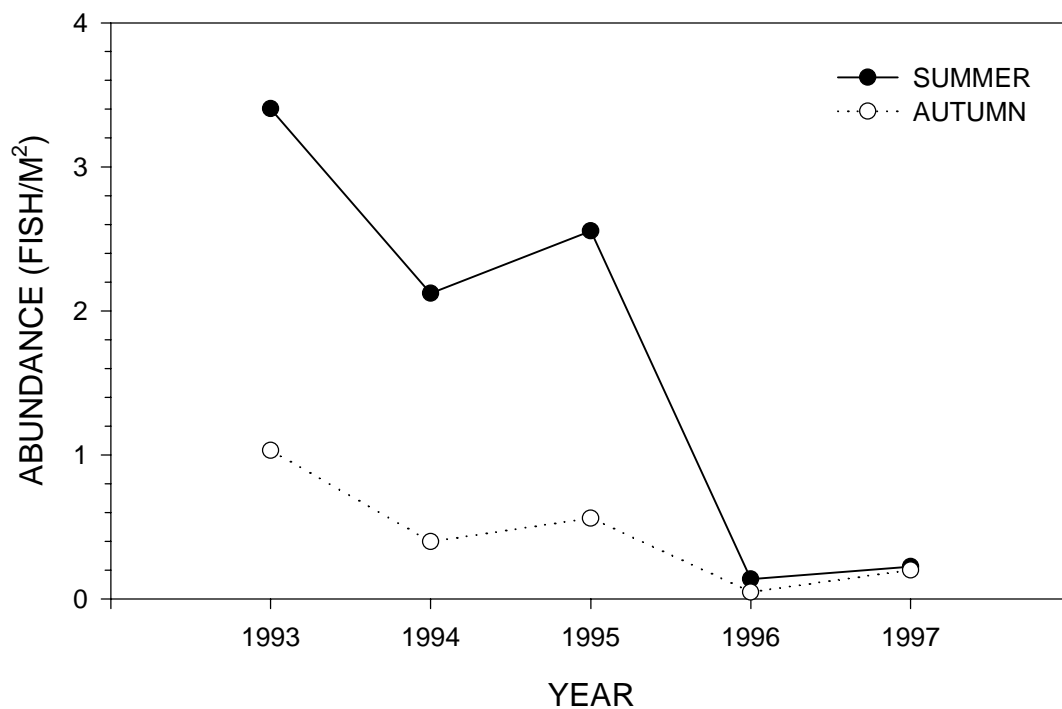
Figure 87. Summer and autumn abundance (fish/m^2, reaches combined) of speckled dace, *Rhinichthys osculus*, in San Juan River secondary channels, 1993 - 1997.
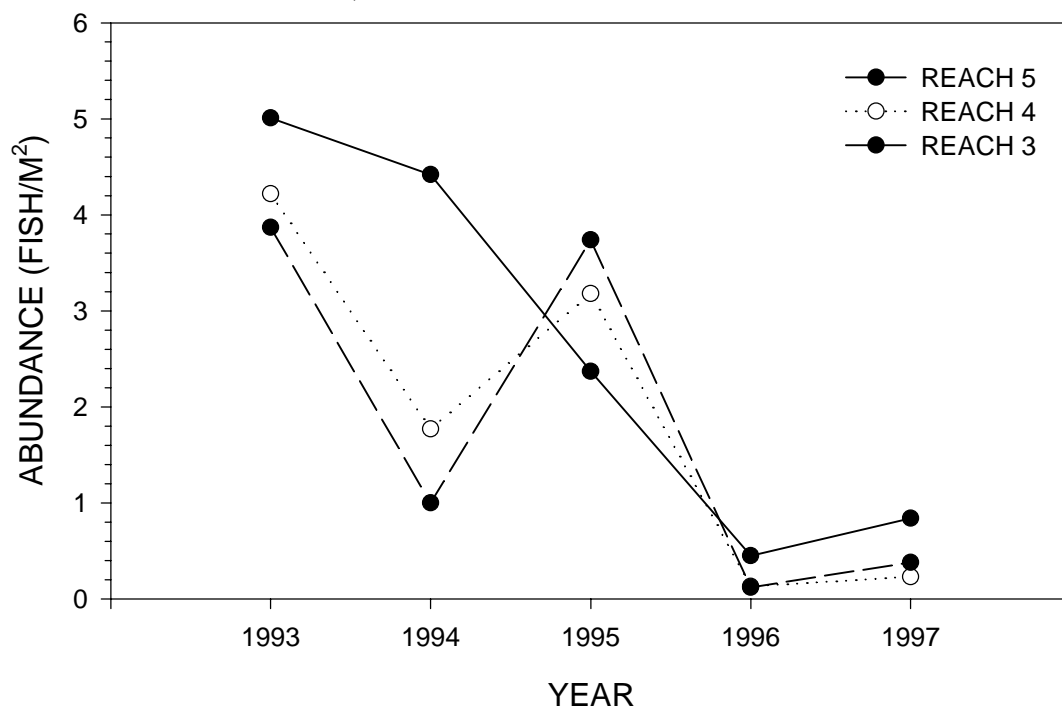
Figure 88. Reach abundance (fish/m^2, seasons combined) of speckled dace, *Rhinichthys osculus*, in San Juan River secondary channels, 1993 - 1997.
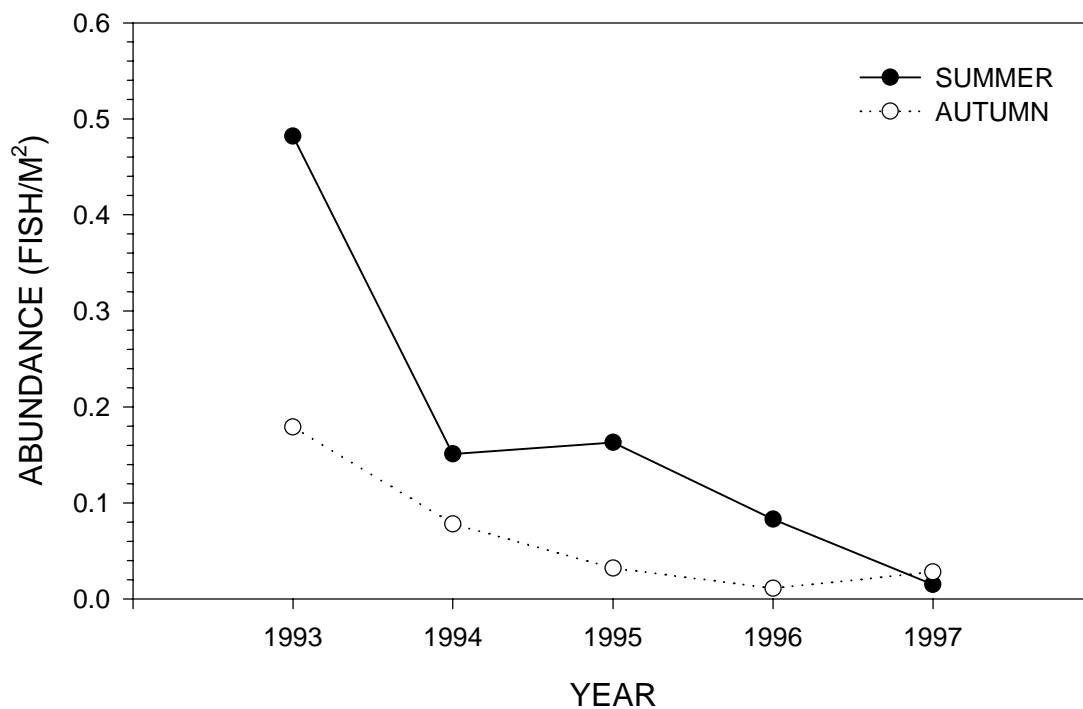
Figure 89. Summer and autumn abundance (fish/m^2, reaches combined) of flannelmouth sucker, *Catostomus latipinnis*, in San Juan River secondary channels, 1993 - 1997.
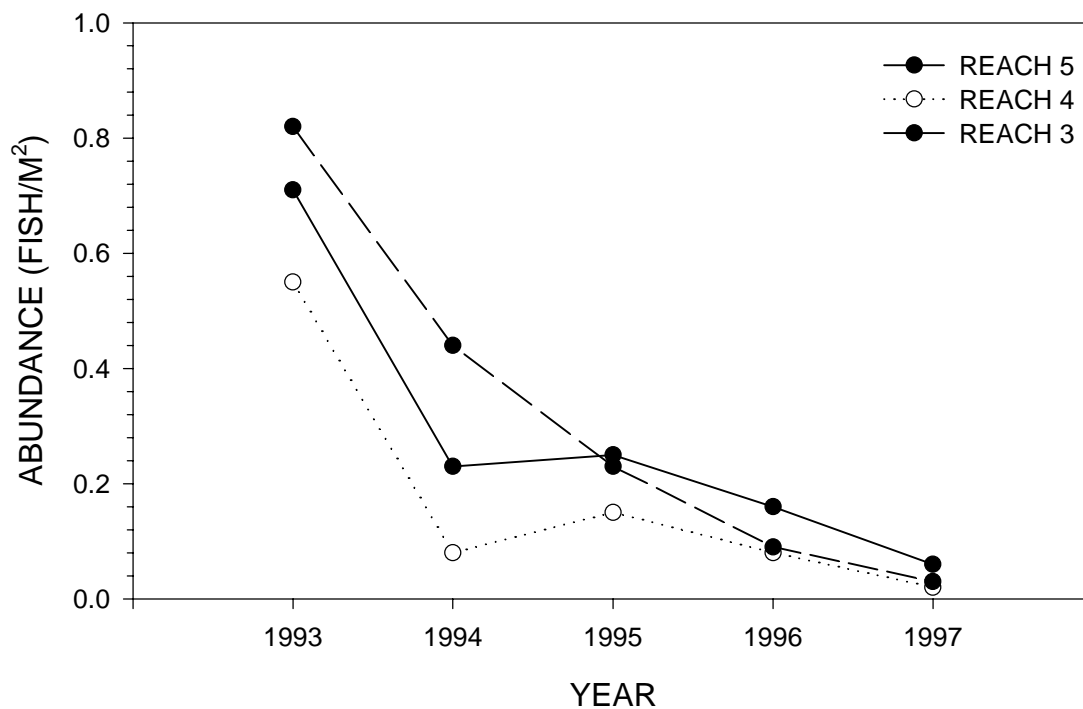
Figure 90. Reach abundance (fish/m^2, seasons combined) of flannelmouth sucker, *Catostomus latipinnis*, in San Juan River secondary channels, 1993 - 1997.
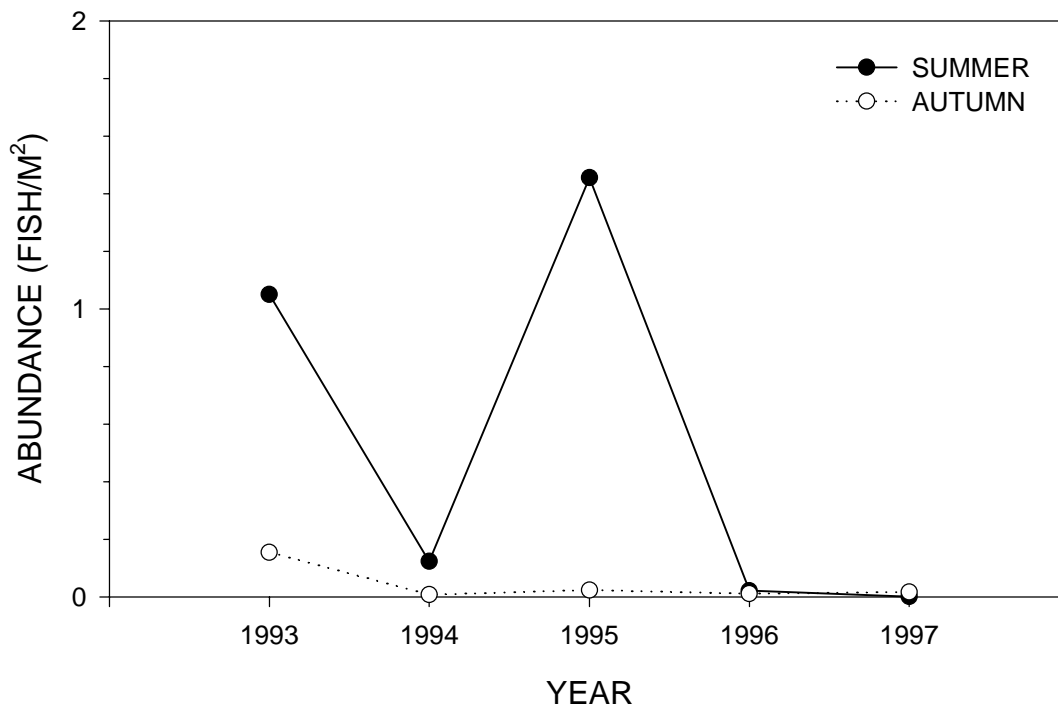
Figure 91. Summer and autumn abundance (fish/m^2, reaches combined) of bluehead sucker, *Catostomus discobolus*, in San Juan River secondary channels, 1993 - 1997.
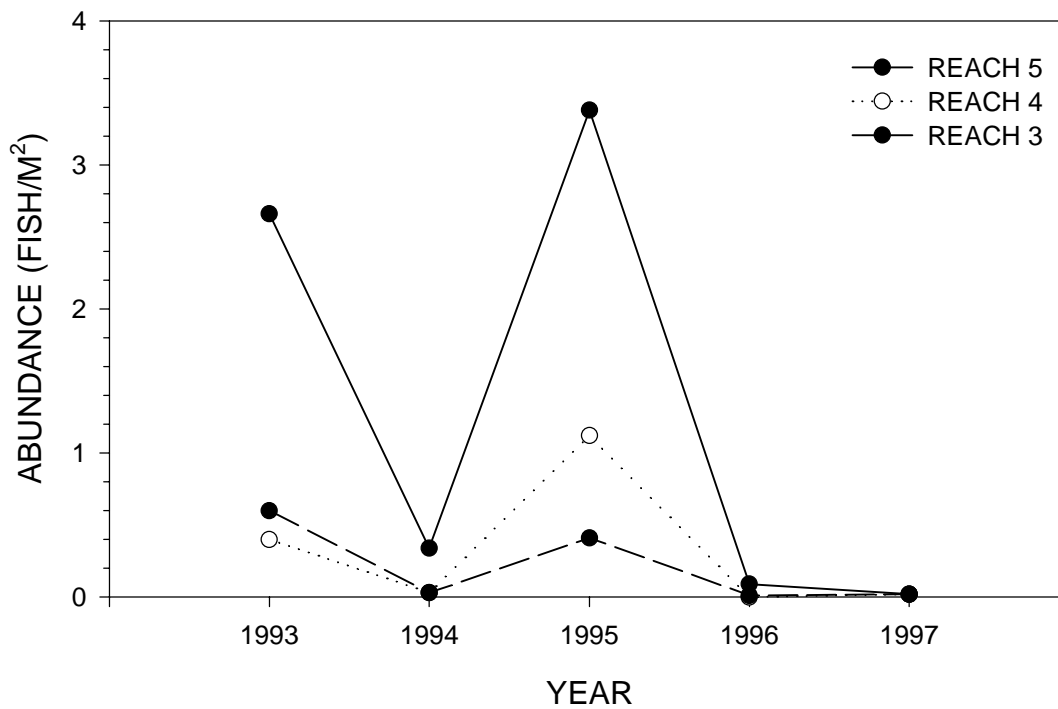
Figure 92. Reach abundance (fish/m^2, seasons combined) of bluehead sucker, *Catostomus discobolus*, in San Juan River secondary channels, 1993 - 1997.
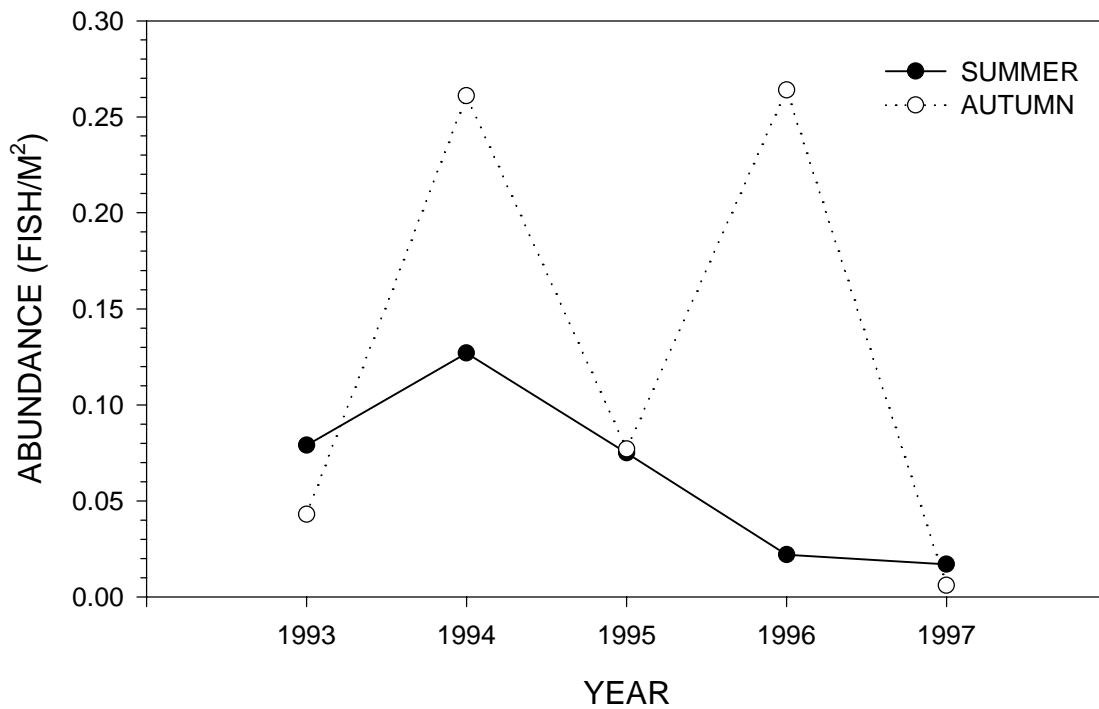
Figure 93. Summer and autumn abundance (fish/m^2, reaches combined) of western mosquitofish, *Gambusia affinis*, in San Juan River secondary channels, 1993 - 1997.
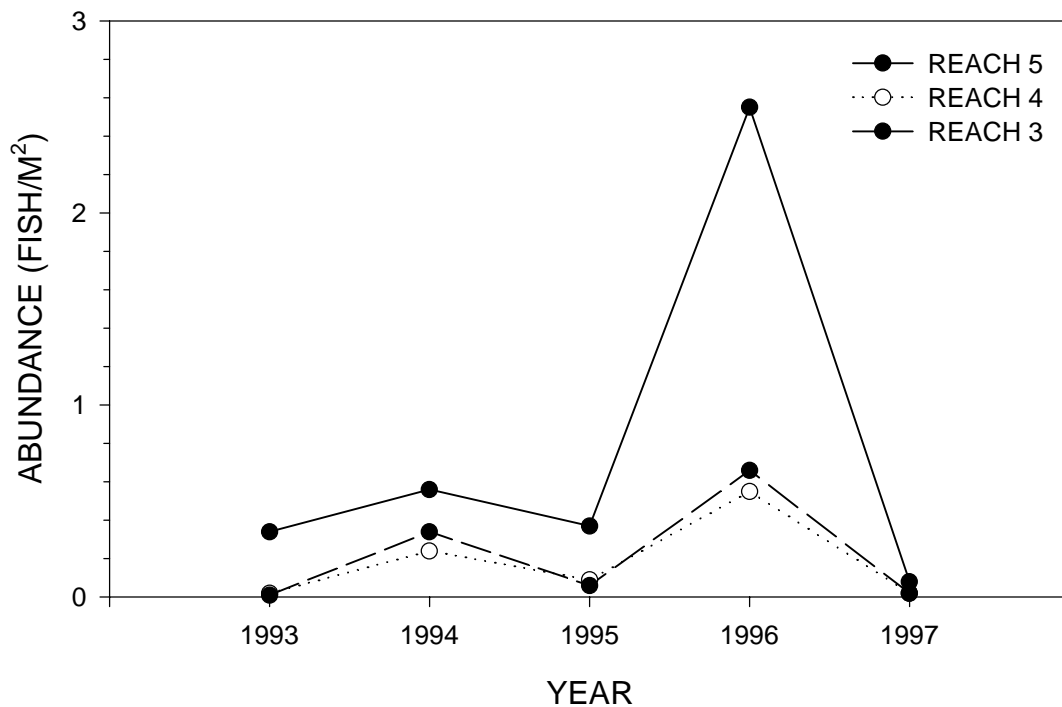
Figure 94. Reach abundance (fish/m^2, seasons combined) of western mosquitofish, *Gambusia affinis*, in San Juan River secondary channels, 1993 - 1997.
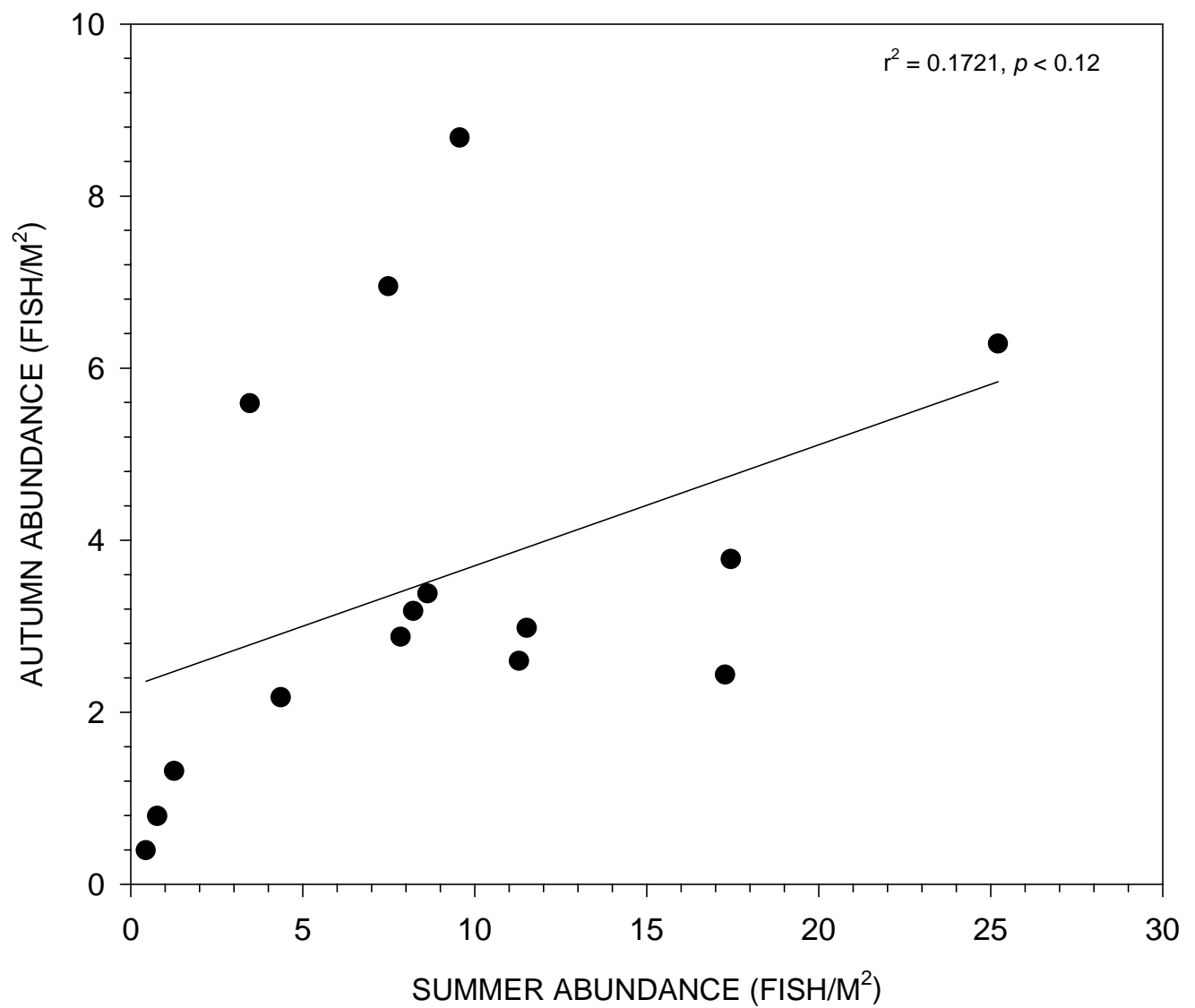
Figure 95. Total summer versus total autumn abundance (fish/m^2) in San Juan River secondary channels, 1993 - 1997.
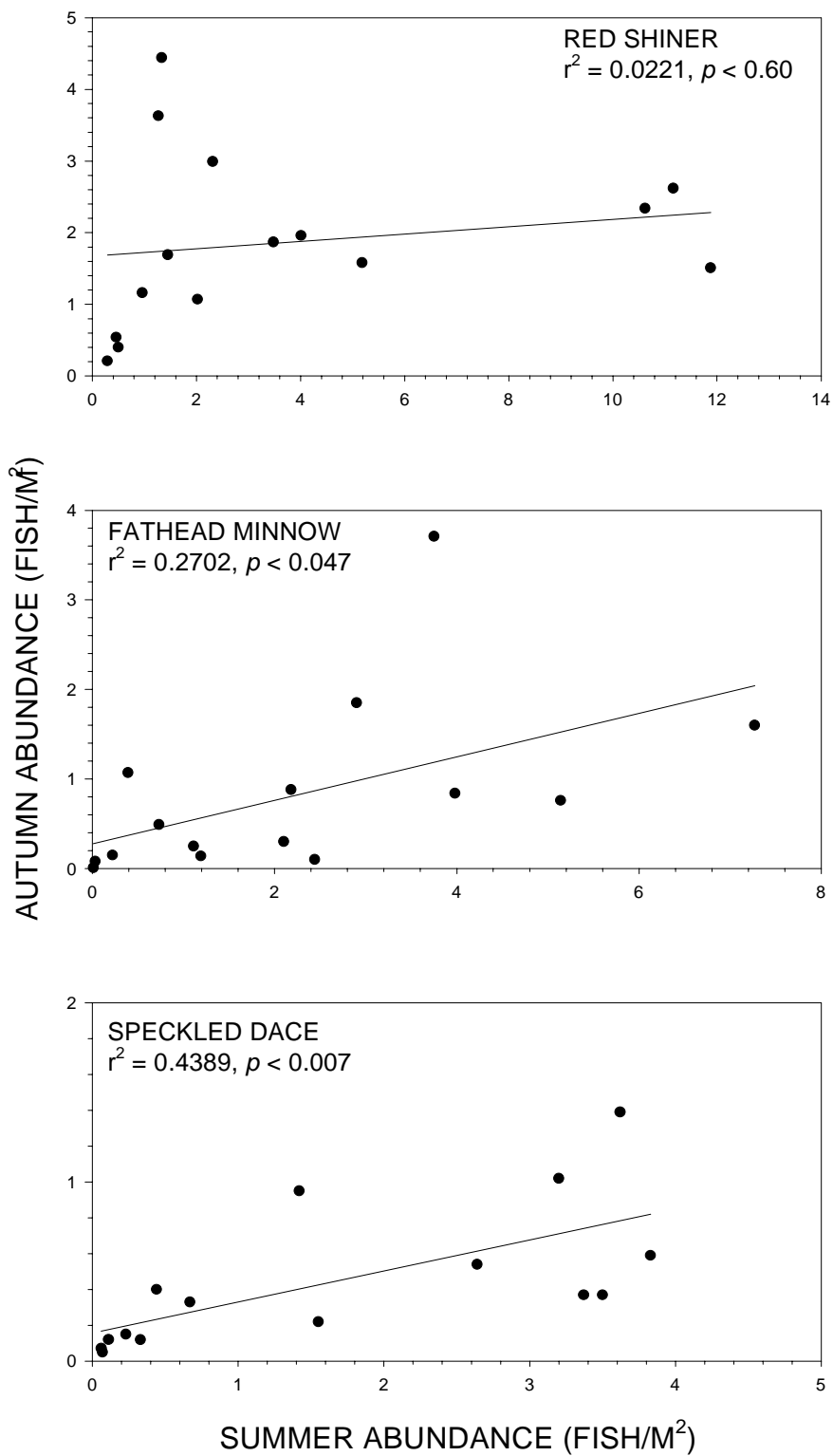
Figure 96. Summer versus autumn abundance (fish/m^2) of red shiner, fathead minnow, and speckled dace in San Juan River secondary channels, 1993 - 1997.
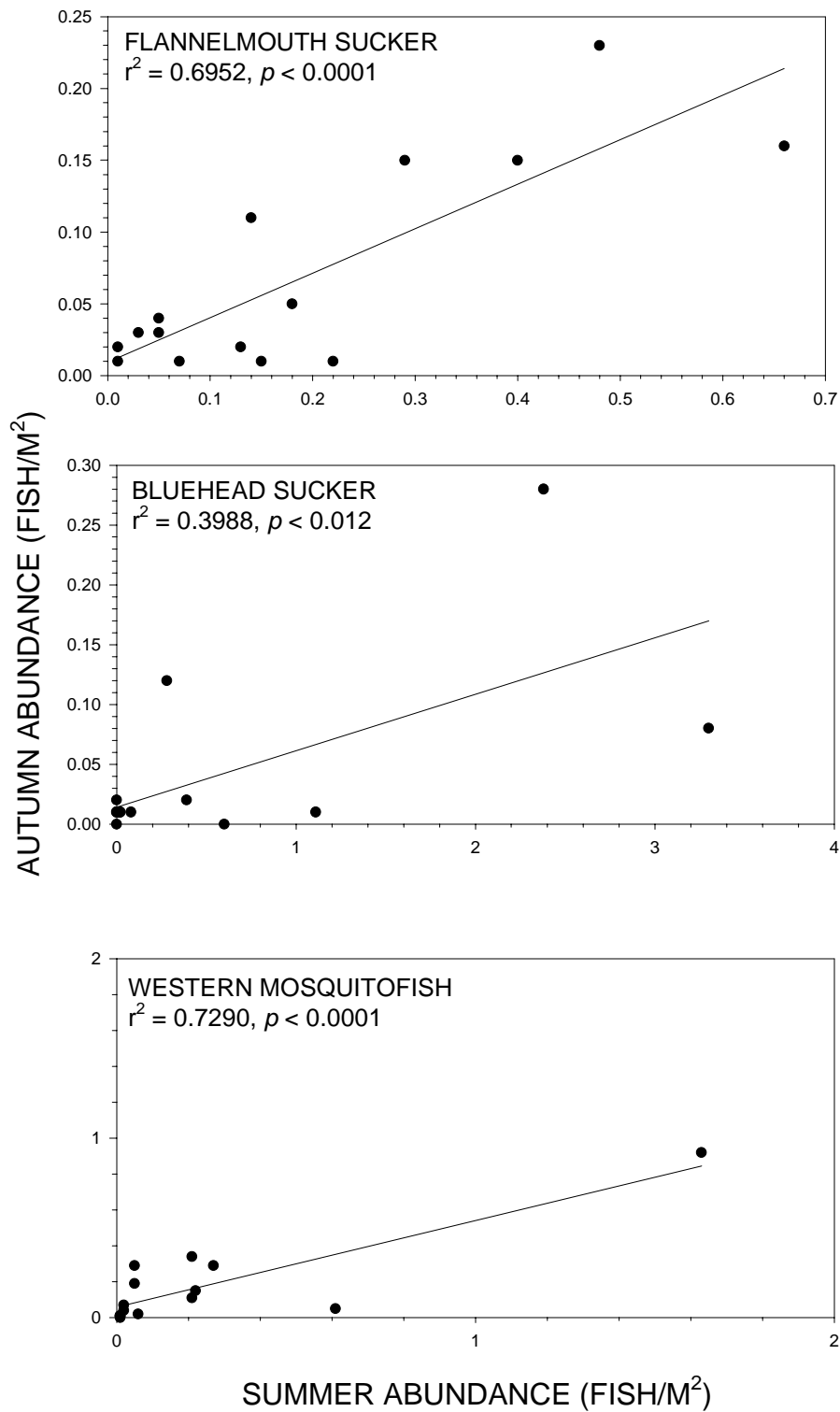
Figure 97. Summer versus autumn abundance (fish/m^2) of flannelmouth sucker, bluehead sucker, and western mosquitofish in San Juan River secondary channels, 1993 - 1997.
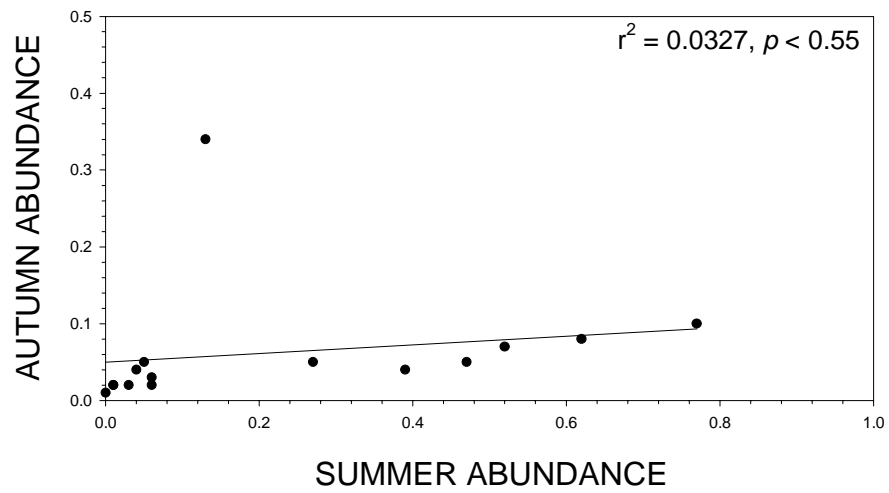
Figure 98. Summer versus autumn abundance (fish/m^2) of channel
catfish in San Juan River secondary channels, 1993 - 1997.

FISH ASSEMBLAGES OF SAN JUAN RIVER

SECONDARY CHANNELS

DISCUSSION

1991 – 1997

DISCUSSION

In the San Juan River between RM 155 and RM 68, secondary channels were common and provided substantial habitat for resident fishes. The availability of secondary channel habitats varied considerably with flow volume. During spring runoff in most years, all secondary channels had surface flow and a range of habitats was available to fishes. As flows receded with the end of spring runoff, the quantity of secondary channel habitats diminished, and in some instances the quality of available habitats may have decreased. For the remainder of the year, flows were fairly low, typically less than 2000 cfs. During summer, convectional storms caused spikes in river discharge and secondary channels that were dry or only had scattered pools and short runs had surface flow for brief periods (normally less than one week) for their entire lengths. Under these conditions, the fish assemblages of San Juan River secondary channels varied considerably over the course of a year. During spring runoff, large-bodied fishes numerically dominated collections, but by late summer most individuals found in secondary channels were mainly representatives of small-bodied species.

During spring runoff, discharge in all years of the study was sufficient to inundate all or most secondary channels associated with the primary channel of the San Juan River. Secondary channels provided habitats for fishes during periods of elevated flow (> 2500 cfs) that were unavailable or unsuitable for much of the year. When discharge was < 1500 cfs (mid summer through winter) few secondary channels had sufficient inflow to maintain flowing water throughout their courses, many had interrupted flow, and some were completely dry except for their downstream confluence with the primary channel. During low-flow periods , large-bodied fishes (> 200 mm TL) were rarely collected in secondary channels and then only in those with surface flow throughout their courses; native and nonnative small-bodied fishes (< 200 and most < 100 mm TL) were common. However, when elevated flows flooded secondary channels, large-bodied fishes quickly moved into secondary channels and were often common. For example, sampling in spring 1996 occurred about 1 week after increasing discharge crossed the 1500 cfs threshold for inundation of 75% of the secondary channels and large-bodied fishes were common in secondary channels.

There are at least three possible reasons for movement of large-bodied fishes into secondary channels during spring runoff. Seasonally, secondary channels may provide foraging areas for each of the commonly collected large-bodied fishes. Both sucker species are benthic feeders; flannelmouth sucker consumes plant material (filamentous algae and vascular plants) and aquatic macroinvertebrates (LaRivers, 1962; Greger and Deacon, 1988) while bluehead sucker survives by scrapping vegetation (including diatoms) from rocks (Baxter and Simon, 1970). Young of both sucker species consume large numbers of aquatic insects, particularly chronomid larvae (Childs et al., 1998). Common carp are omnivores, feeding on vegetation (algae and vascular plants), seeds, and macroinvertebrates (Rehder, 1959; Eder and Carlson, 1977). Channel catfish are largely insectivorous as smaller individuals (< 300 mm TL), but shift to piscivory as they grow (Tyus and Nikirk, 1990; Marsh and Douglas, 1997; Larson and Propst, 1999;

Brooks et al., 2000). Food for each of these species was available, and often common, in San Juan River secondary channels during spring runoff.

A second reason for the apparent high use of secondary channels is for spawning by flannelmouth sucker, bluehead sucker, and common carp. Both sucker species spawn during flow increases associated with spring runoff when water temperatures are 14 to 16°C (Muth and Nesler, 1993). Common carp also spawn in spring when water temperatures are about 15°c (Rehder, 1959). Spawning aggregations of both sucker species, but most frequently flannelmouth sucker, were found over cobble bars where water velocity was rapid (> 1.0 m/s) in several secondary channels during most years. Gravid females and ripe males of common carp were also common during spring in secondary channels.

A third, but less likely, reason was avoidance of the higher velocity flows in the primary channel. Flows at time of spring sampling were less than spring peaks and would not seem sufficient to "force" fish into "protected" areas or channels. In addition, both native sucker species are adapted to the characteristic high spring flows of the San Juan River (Holden and Stalnaker, 1975) and avoidance of primary channel high velocity flows does not therefore seem a reasonable explanation. Channel catfish, likewise, is a riverine species (Pellett et al., 1998), but also inhabits lentic systems (Carlander, 1969). Young channel catfish occur in a wide range of water velocities (Conklin et al., 1996) whereas older individuals are often found in low-velocity areas. Common carp inhabits lentic and lotic habitats and given its wide distribution and success in North American (Moyle, 1976) elevated spring flows would not appear sufficient to prompt it to move to lower velocity areas.

Any, and all, of the above reasons may have contributed to movement of large-bodied fishes into secondary channels as they became inundated or fish simply moved into secondary channels because access was possible. Comparison of primary and secondary channel data for spring 1994 through 1997 indicated some differences in large-bodied fish assemblages. For example, flannelmouth sucker was more common in secondary than the primary channels, but mean biomass of individuals captured was not. Bluehead sucker was more common in secondary channels in Reach 5, but there were no significant differences in abundance in downstream Reaches 4 and 3. Several differences (biomass and abundance) were noted for common carp and channel catfish, but most comparisons indicated about equal usage of primary and secondary habitats by these two species. These comparisons suggested that native suckers, at least smaller individuals, may "seek" secondary channels during spring runoff, but no "preference" for them was indicated by common carp and channel catfish comparisons.

The spring abundance trend of commonly collected species varied. Between 1993 and 1997, abundance of flannelmouth sucker declined in secondary channels in Reaches 5, 4, and 3. The abundance of bluehead sucker initially declined (1993 through 1995), but then increased, in each Reach, from the 1995 low though 1997. The abundance trend of common carp was not consistent among reaches; it generally increased in Reach 5, decreased and then increased in Reach 4, and reversed abundance each year in Reach 3.

Abundance of channel catfish was lowest in all reaches in 1994 and increased in all through the end of the study. The abundance of native flannelmouth and bluehead suckers was lower in 1997 than 1993 in all reaches but that of nonnative common carp and channel catfish was higher in all reaches in 1997 than 1993. There is no obvious explanation for these observed changes. Changes may be related to reproductive success in preceding years (prior to and during study), which, in turn, was influenced by annual discharge patterns (see below). For most fish species, but particularly large-bodied species, seven years was probably too brief to precisely determine patterns, or lack, in abundance as a response to mimicry of a natural hydrograph. Large-bodied species are long-lived ($\geq$ 7 years) and perceived changes in abundance may be a reflection of cohort abundance rather than total abundance. For example, the comparatively high abundance of flannelmouth sucker in spring 1993 and 1994 may have been a reflection of elevated reproductive success and recruitment of the 1987 year class (a high spring runoff year). Its comparatively low abundance in 1995 and 1996 may have been a consequence of low reproductive success and recruitment of the 1989 and 1990 year classes (both low spring runoff years).

Similar to temporal changes in abundance, each commonly collected species had spatial trends in abundance. Flannelmouth sucker abundance was greatest in Reach 4 and least in Reach 5. Bluehead sucker abundance decreased from Reach 5 through Reach 3, where it was incidental in spring collections. Common carp abundance was lowest in Reach 4 and almost equal in Reaches 5 and 3. Channel catfish was most abundant in Reach 3 and least in Reach 4. These overall patterns were generally consistent with that noted for each year. The spatial abundance patterns of flannelmouth and bluehead suckers are likely related, at least in part, to the habitat preferences of each. Because bluehead sucker obtains much of its sustenance by scrapping rocks for vegetation, its distribution in the San Juan River system was partially influenced by the relative abundance of habitats with cobble substrates; such areas were more common in Reach 5 than Reach 4 and Reach 4 than Reach 3 (Bliesner and Lamarra, 1996). The generalist, bottom-feeding habits of flannelmouth sucker may explain its higher abundance in Reach 4. There the abundance of mixed-bottom types were high (Bliesner and Lamarra, 1996). The high island count (an indicator of habitat complexity) of Reach 4 may have contributed to the high abundance of common carp. During spring inventories, common carp were frequently captured in shallow, recently-flooded terraces associated with secondary channels. From 1993 through 1996, abundance of channel catfish was low ($\leq$ 0.20 fish/min) in all reaches (except Reach 3 in 1996). The 1997 increase in channel catfish abundance in Reaches 4 and 3 was, in part, the consequence of relatively high numbers of younger and smaller individuals (< 225 mm TL). These fish were likely spawned in 1995 or 1994, years of high and average spring runoff.

Although some inter-year changes in the size-structure of flannelmouth sucker populations were discerned from length-frequency histograms, none were significant. Within each reach, the age-structure of flannelmouth sucker remained similar from year to year. In Reaches 5 and 4, sub-adults were the most abundant age-class in all years except 1997 when adults were most abundant. In Reach 3, sub-adults were always the most abundant age-class and more abundant by a large margin in most years. Mean total

length of flannelmouth sucker did not change from year to year until 1997 when it increased in Reaches 4 and 3. The increases in mean TL may be a reflection of reduced spawning success and recruitment of the 1996 cohort and survival of the 1995 cohort. Prior to 1997, juveniles (Ages 1 and 2; 76 to 200 mm TL) were at least 12% of annual collections in Reach 4 and at least 20% of the annual Reach 3 collections. In 1997, abundance of juveniles was markedly lower in both reaches. Flows during 1996 were the lowest of the study period and likely contributed to increased mortality of young flannelmouth sucker or reduced spawning success. Thus, paucity of young (and short) individuals in the 1997 collections resulted in an increase in mean length. In Reach 5, juveniles were a large proportion of the 1997 sample and mean length for 1997 was therefore not substantially different than in preceding years. Survival of juveniles may have been enhanced by greater availability of juvenile habitats in Reach 5 than downstream reaches.

Although they were never abundant in secondary channel collections, juvenile, sub-adult, and adult bluehead suckers were present in all reaches in most years. In Reach 5, adults were usually the most numerous age-class while sub-adults were typically more common in Reaches 4 and 3. Mean length of bluehead sucker varied from year to year in Reach 5, but mean TL in 1993 was almost the same as in 1997. Except for a decrease in length in 1994, mean TL was almost identical from year to year in Reach 4. There was a slight decrease in mean TL in Reach 3 during the study. Although there was a marked decline in bluehead sucker abundance between 1993 and 1994 in Reaches 5 and 4, the age- and size-structure data suggest a relative "stability" of bluehead sucker secondary channels populations in each reach.

The size- and age-structure (not plotted in Results as almost all specimens in all reaches in all years were adults) and mean length of common carp remained almost constant throughout the study. Between 1993 and 1997, abundance of common carp increased in Reach 5, remained fairly constant in Reach 4, and varied in Reach 3. Greater numbers of small (< 400 mm TL) common carp were captured in Reach 3 than in Reaches 5 and 4. This may indicate that habitat for juveniles and sub-adults was most common in Reach 3. However, the high abundance of the species in Reach 3 in 1996 was the result of high numbers of adults, not juveniles or sub-adults.

Channel catfish abundance increased in all reaches over the course of the study, but its mean length decreased markedly in all reaches. The decrease in mean length was 50+ mm in all reaches. In contrast, mean TL of other common collected fishes remained the same or increased. In Reach 5, the proportion of large channel catfish (> 500 mmTL) did not change appreciably, but the abundance of individuals < 300 mm was substantially greater in 1997 than 1993. There was no apparent shift in proportion of age- or size-classes in Reach 4; nonetheless mean TL was less in 1997 than 1993. The increase in abundance in Reach 3 was largely attributable to increased abundance of individuals < 250 mm. The decline in mean TL of channel catfish may be a consequence of ongoing efforts to suppress their abundance. If so, the capture techniques (raft electrofishing and hoop nets) may have been selective for large individuals. Alternatively, removal of large individuals may have enhanced survival of small individuals. A third explanation may

involve increased reproductive success or enhanced recruitment. In Reach 3, where juvenile abundance was typically high, the highest abundance was found in 1996 and 1997. Mean TL of the smallest cohort in 1996 was about 160 mm (Range = 100 to 224 mm), indicating they were about Age 2 and therefore spawned in 1994, an average spring runoff year. In 1997, mean TL of the smallest cohort was about 200 mm (Range = 100 to 249 mm) and likely included Age 2 and 3 individuals. The Age 2 fish were spawned in 1995, a high spring runoff year. Data from Reach 3 on the influence of spring runoff on channel catfish reproduction and survival are therefore ambiguous.

During this study, few sub-adult and adult Colorado squawfish or razorback sucker were found in secondary channels during spring inventories. Their rarity in these habitats was more likely a reflection of their overall rarity in the system than an indication of avoidance. In 1996 and 1997, Age-0 Colorado squawfish were stocked in the river. As these fish attain sub-adult and adult sizes, it is likely they will seasonally use habitats provided by secondary channels. Low numbers (< 1000 annually) of sub-adult razorback suckers have been stocked in the San Juan River since October 1994 (Ryden and Pfeifer, 1996) and a few were collected in secondary channels. As numbers stocked increase, or stocked individuals spawn, it is likely that its occurrence in secondary channels will increase.

Data collected on San Juan River fishes during spring inventories indicated shifts in overall assemblage structure of secondary channels. The most apparent reason for these shifts was restoration of a more natural annual flow regime. Between closure of Navajo Dam in 1962 and initiation of the San Juan River Seven Year Research Program in 1991, the annual flow regime was characterized by depressed or truncated spring flows and elevated flows for the remainder of the year. For the seven years of this study, discharge rarely exceeded 2500 cfs during non-spring runoff season, but between 1984 and 1990 discharge frequently exceeded 2500 cfs in all seasons (Table 69). Beginning in 1992, releases from Navajo Reservoir were modified to simulate more natural annual flow regimes with elevated flows during spring and flows near, albeit higher than, historic (pre-dam) levels for the remainder of the year. The shift to more natural flow regimes affected a variety of physical attributes of the river, including habitat availability and quality (Bliesner and Lamarra, 1996). Changes in physical attributes of the system were manifested by changes in the fish assemblages of secondary channels. An essential question is whether these changes were detrimental to the native fish community (including Colorado squawfish and razorback sucker) or will they contribute to restoration of a more "natural balance" among native species and diminished abundance of nonnative fishes. For example, abundance of flannelmouth sucker declined through the study period (1993 through 1997), but size-structure of the population did not. The abundance of flannelmouth sucker prior to restoration of natural flow regimes may have been unnaturally high. Restoration of natural flow regimes may have restored or enhanced mortality factors that were depressed during the period of comparative flow stasis. The lack of change in flannelmouth sucker size- and age-structure suggests that the apparent decline in abundance has not negatively affected the population.

163

Table 68. Number of days San Juan River discharge ≥ 2,500 cfs at Shiprock USGS gage during spring runoff and non-runoff seasons for the seven years preceding initiation of Seven-Year Study and seven years of the study. Spring runoff defined as 1 March through 31 July each year, non-runoff remainder of year. Counts based on water years (1 October – 30 September).

	1984	1985	1986	1987	1988	1989	1990
SPRING RUNOFF	77	140	113	142	17	0	12
NON-RUNOFF	33	31	145	139	11	1	2

	1991	1992	1993	1994	1995	1996	1997
SPRING RUNOFF	20	83	128	65	137	32	90
NON-RUNOFF	0	7	4	0	2	0	19

However, it is unclear from the data obtained in this study if the decline in flannelmouth sucker abundance will continue or has its abundance has reached a new equilibrium.

Data obtained from spring inventories of secondary channels suggest that common carp was impervious to changes in the flow regime (and associated habitat changes). The data did not reveal any apparent trends in abundance, size- or age-structure, or mean length. Changes in attributes of channel catfish populations, however, suggest this species was affected by changes in flow regime. Mean length declined markedly and in Reach 3 abundance steadily increased over the course of the study. Efforts to suppress channel catfish may have influenced these apparent trends.

Spring inventories of San Juan River secondary channels demonstrated that these habitats are seasonally used by all large-bodied fish species present in the San Juan River within the study area (Reaches 5 through 3). This effort also indicated that changes in the flow regime of the river affected secondary channel fish assemblages. It is possible, perhaps likely, that shifts (changes in overall assemblage structure as well as species-specific changes) will continue for several more years.

During summer months (July through September), flows were sufficient in most years of study to inundate at least 50% of the San Juan River secondary channels within the study area. The particular mix of habitats within secondary channels depended upon contemporary and previous flows. Habitats in some secondary channels consisted only of isolated, silt-bottomed pools while others had flowing water with riffle, run, and pool habitats. Regardless of the type and extent of habitats available, fish were almost always found. The species found, and the abundance of each, was mediated, in part, by the habitats present (Gido and Propst, 1999). On a secondary channel scale, considerable differences in habitats available were found and as a consequence the fish assemblages of individual secondary channels often differed substantially. On a Geomorphic Reach

scale, the influence of channel-specific differences diminished as each Reach had a range of secondary channels (and habitats). By grouping fish assemblage data by Reach, channel-specific influences, or aberrations, were reduced and the grouped data thus better represented the overall fish assemblages.

The summer fish assemblages of San Juan River secondary channels were numerically dominated by, often by a large margin, nonnative fish species. Red shiner and fathead minnow were typically the most common fish species. Large numbers of western mosquitofish were found in 1996 (a low-flow year). Speckled dace was relatively common in all years, except 1996. Flannelmouth sucker was moderately common in the 1991 and 1992 collections but was less abundant in subsequent years. Summer secondary channel abundance of bluehead sucker was greatest in 1995 (a high spring runoff year) when it was almost 12% of the total collection; in other years its abundance was low.

In addition to characterizing the fish fauna of secondary channels, this study was designed to gain insights to seasonal changes in their fish assemblages and to characterize the response of these assemblages to different flow regimes. A basic hypothesis was that different flow regimes would be reflected by numeric differences among species. The mechanisms by which different flow regimes affected individual species populations were not known. For example, did elevated flows differentially displace native or nonnative fishes? Did low flows result in habitat loss to the detriment of native or nonnative species? Did altered flow regimes change thermal regimes to the benefit or detriment of a particular species? Were certain life stages more susceptible to changes in flow regime than others? Alternatively, changes in flow and habitat availability may have had no discernable effect on abundance of species. In such a scenario, there would be no "controlling" factors, just random variation in abundance.

The summer fish assemblage of San Juan River secondary channels was quite different from that found during spring runoff. Although the species present did not change, the abundance and size-structure of each species was different. For example, in spring large-bodied flannelmouth sucker, bluehead sucker, common carp, and channel catfish numerically dominated collections, but in summer these species were uncommon and most individuals of each were small (< 150 mm TL). Summer collections were numerically dominated by all age-classes of small-bodied species, particularly red shiner, fathead minnow, and speckled dace.

Some research indicates that elevated flows, particularly floods, diminish the abundance of nonnative fishes (e.g., Minckley and Meffe, 1986; Gido et al., 1997) and do not have a detrimental effect on native fish assemblages. Minckley and Meffe (1986) suggested that the evolution of native western North American fishes in highly varible systems enables them to survive the rigors imposed by severe flooding, but nonnative fishes, most from mesic regions with less severe flooding, are not able to withstand floods typical of the arid west.

In the unregulated San Juan River, the most "predictable" flood was annual spring runoff. Although volume and duration changed substantially from year to year, some elevation in flow occurred in all years during spring. Other floods were associated with storm events, particularly summer convectional storms. However, Navajo Dam enabled regulation of the natural flows of the river and resulted in a reduction (and sometimes elimination in low runoff years) of elevated spring flows. In addition, reservoir releases to meet irrigation needs increased base flows during traditional low-flow periods (summer and early autumn).

During summer, the majority of fishes found in secondary channels were Age-0 individuals. Nonnative red shiner and fathead minnow and native speckled dace were most common. Native flannelmouth and bluehead suckers were typically present, but were not normally common. Western mosquitofish was occasionally abundant, but most other nonnative species collected were uncommon in all years. Channel catfish and common carp, both common during spring inventories, were rare in most summer secondary channels during summer. Few roundtail chub and Colorado squawfish were found in secondary channels during summer. This was largely a function of their overall rarity in the system.

Although abundance of each species varied considerably among years and among Geomorphic Reaches, general (all years combined) longitudinal patterns of abundance were discerned (Figure 100). The abundance pattern of each was related, at least in part, to their habitat preferences and life history strategies. Bluehead sucker was substantially more abundant in Reach 5 ($1.02/m^2$) than downstream reaches (0.27 and $0.14/m^2$). Speckled dace and fathead minnow had similar, but less dramatic, patterns. Bluehead sucker feeds on perilithic plants; cobble-bottomed riffles and runs with seasonally abundant vegetation were more common in Reach 5 than downstream reaches (Bliesner and Lamarra, 1996). In addition, such areas are also the primary spawning habitat of the species (McAda and Wydoski, 1983; Maddux and Kepner, 1988). The comparatively high abundance of Age-0 bluehead sucker (versus flannelmouth sucker) in secondary channels during summer may be related to bluehead sucker spawning later in spring than flannelmouth sucker. By the time of summer inventories (mid August), Age-0 flannelmouth sucker had moved from secondary channels habitats to the primary channel, but later-spawned bluehead sucker remained in the low-velocity habitats of secondary channels. The summer longitudinal abundance pattern of bluehead sucker reflected its spring abundance pattern. Although speckled dace was most commonly associated with riffles, it also occurred in other habitats with flowing and standing water (Minckley, 1973; Gido and Propst, 1999). Variety of habitats used coupled with feeding habits (insectivorous) explains, in part, the slightly decreasing longitudinal abundance pattern of speckled dace. The comparatively high abundance of fathead minnow in Reach 5 and lower abundance in Reach 3 may be related to the reproductive biology of the species. Males establish territories near submerged debris or vertical and undercut banks in low-velocity water and the adhesive eggs are deposited on instream structures (Becker, 1983). Areas with requisite physical features for fathead minnow spawning were comparatively common in secondary channels in Reach 5 but less so in downstream reaches. The relative rarity of flannelmouth sucker in secondary channels during summer

may be more a function of time of sampling than avoidance or non-use of secondary channels. Red shiner was the only commonly collected species that was most abundant in Reach 4. Habitat availability and thermal regime may have contributed to its higher abundance in Reach 4. The convergence of optimal water temperature for spawning (22 to 26°C) and habitat (gravel- and small cobble-bottomed riffles)(Gale, 1986) likely occurred in Reach 4.

Comparison of summer abundance of commonly collected species to attributes of spring runoff indicated that there were positive relationships for several species. The greatest abundance of fishes in secondary channels was in 1993 and 1995, high spring runoff years. Regression analysis revealed positive, if not significant, relationships between spring runoff and summer densities of several species. Red shiner abundance was most strongly correlated, but not significantly, to spring runoff in Reach 4. Speckled dace abundance was significantly related to most attributes of spring runoff in Reaches 4 and 3 and bluehead sucker abundance was strongly correlated with spring runoff attributes in Reach 5. Neither fathead minnow nor channel catfish abundance appeared to be related to spring runoff.

The lowest summer abundance of all species, native and nonnative, was in 1997, a year of high spring runoff. The low abundance of fishes in 1997 seemingly contradicts the presumed positive relationship between spring runoff and summer abundance of several species. Several factors, however, may have caused this apparent anomaly. Spring runoff in 1996 was lower than in any other year of the study. While abundance of all fishes was lower in 1996 than 1995, native fishes declined more than nonnatives (native fishes were 34.3% of the fishes collected in 1995 but in 1996 native fishes were only 15.0% of the collections). Between 1995 and 1996, total abundance of red shiner declined from 5.73 to 2.50/m^2, but speckled dace declined from 2.56 to 0.14/m^2 and bluehead sucker from 1.46 to 0.02/m^2. These summary data suggest that short-lived (and small-bodied) nonnative fishes had greater reproductive success or survival of young than did speckled dace (also a short-lived species) in 1996. Native fishes spawn primarily during spring runoff or runoff recession while the two most common nonnatives spawn after runoff recession. If spring runoff is low, native fish reproductive success, or survival of young, is presumably lowered. The low abundance of all species, particularly short-lived, in summer 1997 was in part a consequence of low numbers of 1996 year-class individuals. The high spring runoff of 1997 likely had a relatively greater positive effect on the reproductive success of native than nonnative fishes; native fishes were a larger proportion of the collections in summer 1997 than in 1996, lending some credence to this scenario.

During summer, San Juan River secondary channels provide habitats used by native and nonnative fishes, particularly Age-0 individuals (Gido and Propst, 1999). Red shiner, fathead minnow, and speckled dace spawn in secondary channels and this contributes to their summer abundance in these habitats. Flannelmouth and bluehead
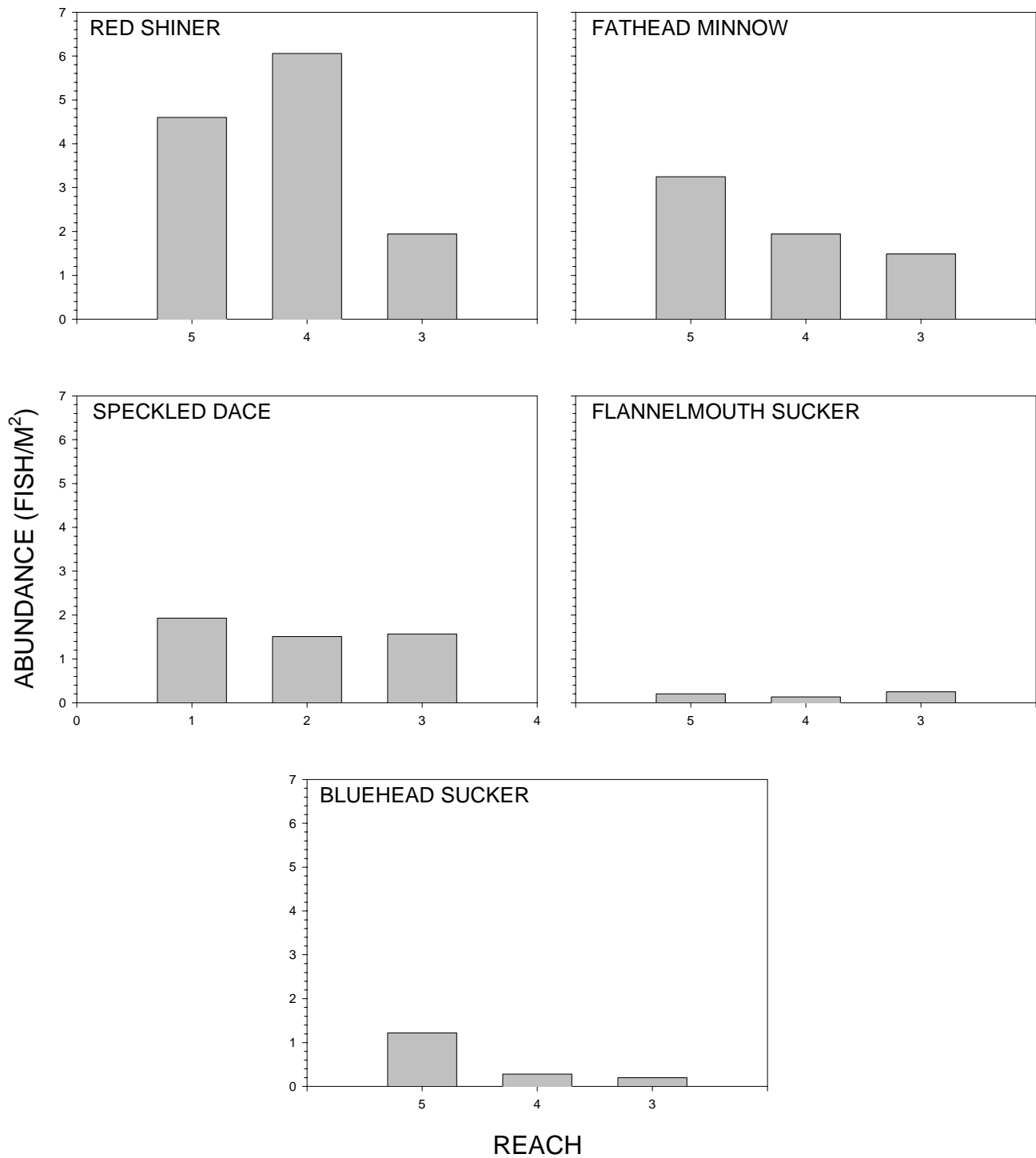
167

Figure 99. Mean summer abundance of commonly collected fish species in San Juan River secondary channels, 1993 - 1997.

may spawn in secondary channels during spring runoff or their young drift into secondary channels. Regardless of their origin, native suckers were typically a small proportion of secondary channel summer fish assemblages. With few exceptions, no age-class of either common carp or channel catfish was common in secondary channels during summer. Their paucity suggests that during summer secondary channels have limited amounts of the habitats these species need or use.

By autumn abundance of fishes in secondary channels was substantially less than in summer, but the species present and their rank did not change noticeably. Although there were some changes in habitat, these were minor; autumn flows were about the same or slightly greater than during summer. During 1993 and 1997, summer storms caused flow spikes but in other years flow was comparatively constant from spring runoff recession through autumn.

Mean autumn longitudinal abundance trends of red shiner and fathead minnow were different from that noted for summer. In average, red shiner abundance was greatest in Reach 4 in summer, but greatest in Reach 3 in autumn (Figure 101). In summer, fathead minnow abundance decreased in a downstream direction, but was least in Reach 4 in autumn and almost equal in Reaches 5 and 3. In contrast, native fish (speckled dace, flannelmouth sucker, and bluehead sucker) abundance trends changed little between summer and autumn. Speckled dace was most abundant in Reach 5 in both seasons, but the downstream decrease was more pronounced in autumn than summer.

Generally, low summer flows and absence of flow spikes benefited nonnative fishes, particularly fathead minnow. Native fishes were negatively affected by low summer flows (especially number of days discharge < 500 cfs) and elevated summer flows (including flow spikes) did not have an apparent effect (negative or positive) on native fish abundance.

The most likely reason for the positive effect of low summer flows on the autumn abundance of nonnative fishes (red shiner, fathead minnow, and western mosquitofish) was related to their requirements for spawning and tolerance of elevated temperature and depressed dissolved oxygen (Matthews and Hill, 1979; Fader et al., 1994; Hubbs, 1996). Each spawns when water temperatures exceed 20°C. Water temperatures do not normally attain this level until after recession of spring runoff in mid to late July, and rarely exceeded 25°. Water temperatures typically drop 5°C or more during summer flow spikes. In 1993, 1994, and 1996, there were no substantial summer flow spikes; red shiner autumn abundance was highest in these years. In 1995 and 1997, years having summer flow spikes, red shiner abundance was comparatively low (although not considerably lower in 1995). Fathead minnow and western mosquitofish autumn abundance was highest in 1994 and 1996 and lowest in 1995 and 1997. Autumn abundance of both was low in 1993, a year with comparatively high spring runoff but no summer flow spikes. Speckled dace autumn abundance was highest in 1993 and 1995, years with high spring runoff and summer flow spikes. Although its autumn abundance in 1997 was low compared to 1993 through 1995 levels, it was substantially higher than

that found in 1996, a low spring runoff year with low base summer flows (and no summer flow spikes). Both flannelmouth and bluehead suckers autumn abundance patterns were similar to that of speckled dace, but with some differences. Flannelmouth sucker abundance was comparatively low in 1995 (high spring runoff year). Autumn abundance of both sucker species was greater in 1997 (high spring runoff and summer flow spikes common) than in 1996 (low spring runoff and no summer flow spikes).

Although secondary channel summer abundance of nonnative red shiner, fathead minnow, and western mosquitofish were depressed somewhat by high spring runoff, the greater negative impact on their autumn abundance appeared to be elevated summer flows (particularly flow spikes). Low summer flows appeared to have no negative effect on their abundance and seemed to enhance that of at least western mosquitofish. The low summer flows of 1996 had a major negative impact on native fishes in secondary channels. In contrast, elevated summer flows did not have discernible negative effects on native fish abundance, but low, stable summer flows depressed native fish abundance. Prior to 1997, paucity of Colorado squawfish and razorback sucker in the San Juan River precluded evaluation of their use of secondary channel habitats. The capture of comparatively large numbers of Colorado squawfish in secondary channels in autumn 1997 indicates the species readily uses habitats (particularly low-velocity) of secondary channels.

The 1991 through 1997 seasonal ichthyofaunal inventories of San Juan River secondary channels demonstrated extensive use of these habitats by native and nonnative fishes. Flow levels appeared to have a major influence on the attributes of the fish assemblages. During spring runoff, large-bodied fishes (native and nonnative) were common in secondary channels, but during low flow periods assemblages were numerically dominated by small-bodied fishes, particularly nonnative red shiner and fathead minnow; native speckled dace was the only common native species in summer and autumn assemblages. The occurrence of large numbers of juvenile Colorado squawfish in autumn 1997 suggested secondary channels provide habitat for the species. Manipulation of flows during summer and early autumn may be a method to control or suppress abundance of undesirable nonnative fish species, particularly small-bodied species such as red shiner, fathead minnow, and western mosquitofish. In contrast, elevated flows during spring have limited negative effects on abundance of several nonnative species but positive effects on abundance of several native fish species.
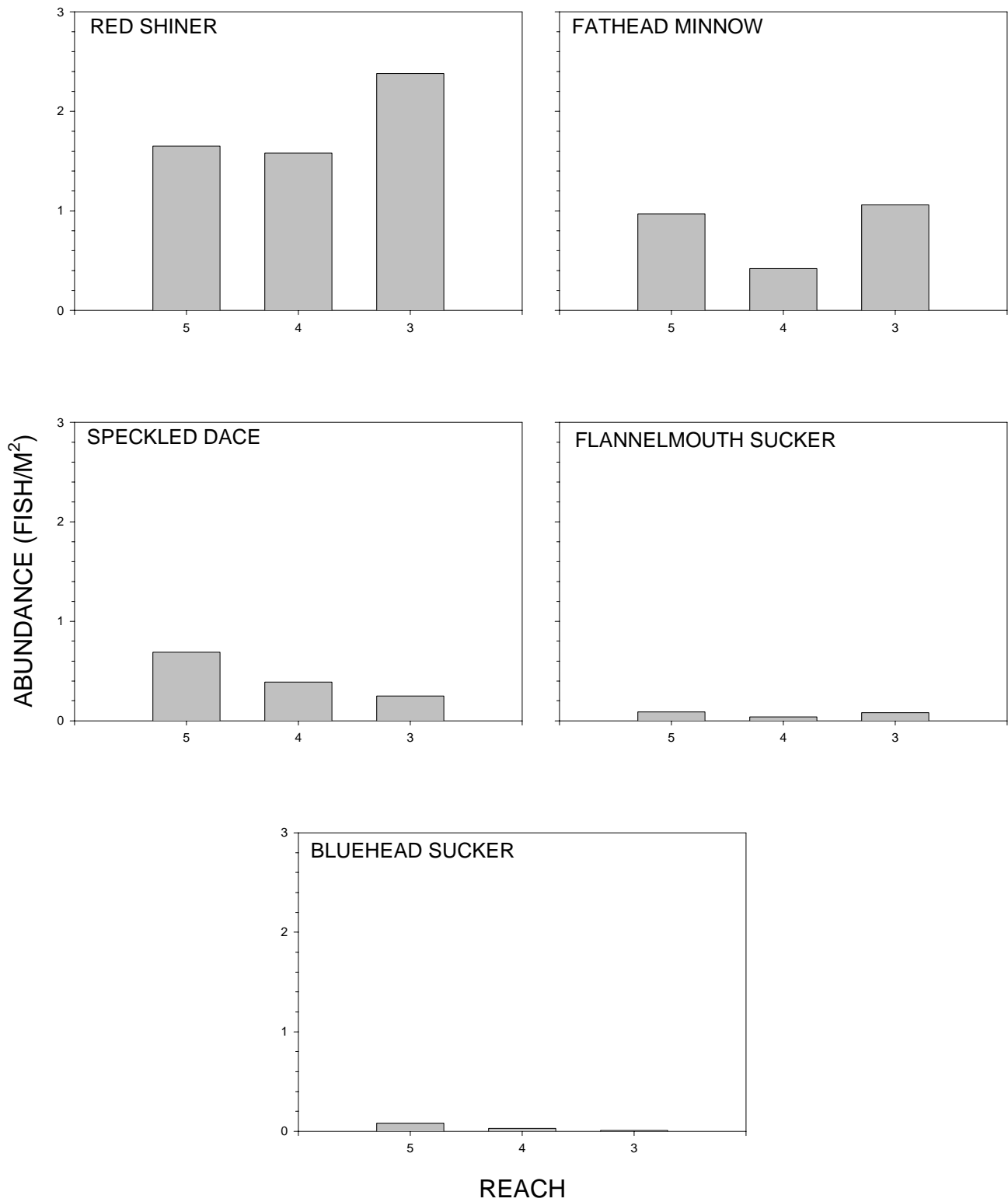
Figure 100. Autumn abundance of commonly collected fish species
in San Juan River secondary channels, 1993 - 1997.

FISH ASSEMBLAGES OF SAN JUAN RIVER

SECONDARY CHANNELS

1991 – 1997

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

OVERALL

♦ Study objectives met?   Yes.

♦ Flows at time of sampling did not effect Spring and Summer CPUE, but negatively effected autumn CPUE.

♦ There are substantial seasonal changes in the fish assemblages of secondary channels.

♦ Secondary channels provide substantial habitat for native and nonnative fishes.

♦ Autumn sampling likely yielded the most representative samples of the small-bodied fish assemblage of secondary channels.

♦ Only spring sampling will provide information on use of secondary channels by large-bodied fishes.

♦ Spring secondary channel assemblages composed mainly of large-bodied individuals of flannelmouth sucker, bluehead sucker, common carp and channel catfish, but sampling technique biased against small-bodied fishes.

♦ Abundance of fishes during spring did not change in Reach 5, declined in Reach 4, and varied but did not change over the course of the study in Reach 3.

♦ Over the course of the study there were distinct changes in the structure of secondary channel spring fish assemblages.

♦ In each season sampled, there were measurable differences in the fish assemblages in Geomorphic Reach.

♦ Summer secondary channel assemblages composed mainly of small-bodied fishes. Red shiner, fathead minnow, and speckled dace most common species during summer.

♦ Autumn secondary channel assemblages composed mainly of small-bodied fishes. Red shiner, fathead minnow, and speckled dace most common species during autumn.

♦ Elevated spring runoff appeared to be positively correlated with summer secondary channel abundance of fishes in secondary channels.

♦ Elevated spring runoff did not appear to have definite negative impacts on any small-bodied species, but had positive effects on summer abundance of several.

♦ Elevated summer flows appeared to be detrimental to abundance of some nonnative species but no, or slightly positive, effect on native fishes.

♦ Low summer flows had a negative impact on abundance of native fishes but had no effect or positive effect on nonnative species.

FLANNELMOUTH SUCKER

♦ Flannelmouth sucker was typically the most abundant species during in all Reaches in all years.

- Spring abundance declined in all reaches (5, 4, and 3), but mean TL remained the same (Reach 5) and was the same from 1993 through 1996 and increased in 1997 (Reaches 4 and 3).
- Spring size- and age-structure remained similar among reaches and years.
- Spring total biomass declined in all reaches, but mean biomass was the same (Reach 5) or increased (Reaches 4 and 3).
- Spring abundance was usually greater in Reaches 5 and 4 than Reach 3.
- Summer abundance varied from 1991 through 1995 and declined to study low in 1997.
- Summer abundance was positively related, but not significantly, to elevated spring discharge; strongest relationships were with days flows exceeded 3,000 and 5,000 cfs.
- Autumn abundance decreased from 1993 through 1996 and increased in 1997.
- Autumn abundance was greatest in Reach 5 and least in Reach 4.
- Autumn abundance was negatively related, but not significantly, to low summer flows and in Reach 3 to days discharge > 1000 cfs.
- Autumn abundance was significantly, and positively, related to summer abundance.
- Sub-adults and adults were rarely found in secondary channels during summer and autumn; most specimens were juveniles and larvae.

BLUEHEAD SUCKER

- Bluehead sucker varied from the second- to fifth-most abundant species in spring inventories.
- Spring abundance declined from 1993 through 1995 in all reaches, and increased through 1997.
- Spring abundance of bluehead sucker was usually greatest in Reach 5 and least in Reach 3.
- Spring size- and age-structure changed slightly during the study; small individuals (<150 mm, Age-0 and –1) were more common in 1993 and 1994.
- Mean TL varied some in Reaches 5 and 4, and declined slightly in Reach 3.
- Total spring biomass was usually greatest in Reach 5 and least in Reach 3.
- Summer abundance peaked in 1993 and 1995, high spring runoff years, and was least in 1991, 1996, and 1997. Spring runoff was low in 1991 and 1996, but high in 1997.
- Summer abundance was positively, and significantly, related to elevated spring runoff, particularly in Reaches 5 and 3.
- Autumn abundance was comparatively high in 1993, but low in all succeeding years.
- Autumn abundance was greatest in Reach 5 and least in Reach 3.
- Summer flow attributes generally had little effect on bluehead sucker autumn abundance; low summer flow had very weak negative effects on autumn abundance.

174

♦ There was weak correlation between summer and autumn abundance of bluehead sucker.

COMMON CARP

♦ Common carp was the second- or third-most abundant species in spring inventories.
♦ Spring abundance was similar from 1993 through 1995 and increased through 1997 in Reaches 5 and 4; abundance varied among years in Reach 3, peaking in 1996.
♦ Abundance was not consistently greater in a single Reach during the study; it was least in Reach 4 in 1995 and greatest in Reach 3 in 1996.
♦ Spring size- and age-structure was similar in all reaches in all years.
♦ Total spring biomass was usually greater in 1996 and 1997 than preceding years.
♦ Total spring biomass was greatest in Reach 5 from 1993 through 1995, greatest in Reach 3 in 1996, and greatest in Reach 5 in 1997.
♦ Mean total length did not change in any reach during the study; mean biomass remained the same in Reach 5 and increased slightly in Reaches 4 and 3.
♦ Common carp was rarely collected in secondary channels during summer and autumn.

CHANNEL CATFISH

♦ Channel catfish was the second- to sixth-most abundant species in spring inventories.
♦ Spring abundance was similar from 1993 through 1996, but increased in 1997 in Reach 5; was similar among years (except 1994) in Reach 4; and increased from 1993 through 1997 in Reach 3.
♦ Adults were the majority of specimens collected in spring from 1993 through 1995, but sub-adult abundance increased in 1996 and 1997. Individuals < 300 mm TL increased, as a proportion of samples, from 1993 through 1997.
♦ Mean spring TL decreased in all reaches.
♦ Total spring biomass decreased from 1993 through 1996 and increased in 1997 in Reach 5, mean biomass declined; total biomass was similar (except 1994) in Reach 4, mean declined; total biomass increased from 1993 through 1995 and remained the same thereafter in Reach 3, mean biomass decreased.
♦ Summer abundance of channel catfish increased from 1991 through 1994 and then declined through 1997.
♦ In Reaches 5 and 3, there was no relationship between spring runoff attributes and summer abundance; in Reach 4 summer abundance was weakly, and positively related to elevated flows.
♦ Autumn abundance declined from 1993 through 1996, and increased slightly in 1997.

- ♦ Autumn abundance was least in Reach 5 and greatest in Reach 3.
- ♦ Autumn abundance was generally negatively related to elevated summer discharge, and significantly so in Reach 4.
- ♦ Summer abundance was not related to autumn abundance.

RED SHINER

- ♦ Spring sampling methods (raft-mounted electrofishing) was not an efficient method of red shiner collection.
- ♦ Insufficient numbers of red shiner were collected to characterize their distribution and status during spring.
- ♦ Red shiner was the most abundant species collected in secondary channels during summer in all years except 1994 and 1996 (low spring runoff years).
- ♦ Total summer abundance of red shiner peaked in 1993 and 1995 (high spring runoff years), and was lowest in 1997 (also a high spring runoff year). Summer and autumn flows were higher in 1997 than 1993 or 1995.
- ♦ Total summer abundance was greatest in Reach 4 and least in Reach 3.
- ♦ Summer abundance was positively, but not significantly, related to elevated spring discharge (except days flow > 5000 cfs in Reaches 4 and 3, which were significant).
- ♦ Red shiner was the most abundant species in autumn in all years.
- ♦ Total autumn abundance was about the same from 1993 through 1995, but declined to study low in 1997.
- ♦ Total autumn abundance was greatest in Reach 3 and least in Reach 4.
- ♦ Autumn abundance was negatively, but not significantly, related to elevated summer flows.
- ♦ Autumn abundance was not correlated with summer abundance.

FATHEAD MINNOW

- ♦ Spring sampling techniques did not yield representative collections of fathead minnow.
- ♦ Spring sampling obtained fathead minnow in all years, except 1997.
- ♦ Total summer fathead minnow abundance peaked in 1993 (high spring runoff), 1994 (low spring runoff), and 1996 (low spring runoff). Total abundance was least in 1997 (high spring runoff).
- ♦ Summer abundance was generally not related to spring runoff levels.
- ♦ Summer abundance was greatest in Reach 5 and least in Reach 3.
- ♦ Total autumn abundance was greatest in 1995 and least in 1997.
- ♦ Autumn total abundance was greatest in Reach 3 and least in Reach 4.
- ♦ Autumn abundance was negatively, but not significantly, related to elevated summer flows; abundance was positively related to days flow < 500 cfs (significantly in Reach 4).

♦ Autumn abundance was significantly related to summer abundance.

SPECKLED DACE

♦ Boat electrofishing was not an effective method for sampling speckled dace during spring inventories.
♦ Speckled dace was collected during each spring inventory and was the most abundant small-bodied species in all years except 1994 and 1996 (low spring runoff years).
♦ During summer, speckled dace was the second- or third-most abundant species in all years except 1996 (low spring runoff and low summer base flows).
♦ Total summer abundance peaked in 1993 (high spring runoff) and was least in 1996 (low spring runoff and low summer base flows).
♦ Total summer abundance was greatest in Reach 5 and least in Reach 4 (only slightly less than Reach 3).
♦ Summer abundance of speckled dace was positively related to all attributes of elevated spring discharge. In reaches 4 and 3, most relationships were significant.
♦ Autumn total abundance decreased from 1993 through 1996 and then increased in 1997.
♦ Autumn total abundance was greatest in Reach 5 and least in Reach 3.
♦ There was no relationship between any summer flow attribute and autumn abundance, except days flow < 500 cfs. That relationship was negative, but not significant, in all reaches.
♦ Autumn abundance was positively, and significantly, related to summer abundance.

WESTERN MOSQUITOFISH

♦ Raft-mounted electrofishing gear failed to capture western mosquitofish during spring inventories.
♦ Total summer abundance was usually low, except in 1996.
♦ Total summer abundance was greatest in Reach 5 and least in Reach 4.
♦ Total autumn abundance peaked in 1994 and 1996 and was least in 1997 (elevated summer flows).
♦ Autumn abundance was greatest in Reach 5 and least in Reach 3.
♦ Autumn abundance was greatest in Reach 5 and least in Reach 3.
♦ Autumn abundance was negatively related to elevated summer flows and positively (significantly in Reaches 5 and 4) related to days flow < 500 cfs.
♦ Autumn abundance was significantly related to summer abundance.

COLORADO PIKEMINNOW

♦ No adult Colorado pikeminnow was captured in secondary channels during spring inventories.
♦ One juvenile Colorado pikeminnow was captured in a secondary channel in 1997.
♦ Colorado pikeminnow was the third most abundant species in secondary channels in autumn 1997. It was not found in secondary channels in preceding years.
♦ Colorado pikeminnow autumn abundance was greatest in Reach 5 and least in Reach 4 in 1997.

RAZORBACK SUCKER

♦ Razorback sucker was found in secondary channels during spring inventories in 1996 and 1997.
♦ No razorback sucker was found in secondary channels during summer or autumn inventories.

ROUNDTAIL CHUB

♦ Roundtail chubs (juveniles) were found in secondary channels during summer and autumn inventories in 1997. None was collected during spring.
♦ Roundtail chub was found in Reaches 4 and 3 during summer but not Reach 5.
♦ During autumn, roundtail chub was found in Reaches 5, 4, and 3.

OTHER NONNATIVE FISHES

♦ During spring inventories, eight nonnative species (in addition to those listed above) were collected. All were rare and none was collected in all years.
♦ Summer inventories yielded four nonnative species (in addition to those listed above). None was collected in all years. Plains killifish was the most common of these but was never abundant.
♦ Autumn inventories yielded the same rare nonnative fishes as found during summer (black bullhead, plains killifish, green sunfish, and largemouth bass).
♦ Plains killifish was the most common rare nonnative fish in autumn collections, but was never abundant.
♦ Centrarchids were rare in San Juan River secondary channels in all seasons.
♦ Ictalurids, except channel catfish, were rare in San Juan River secondary channels in all seasons.

FISH ASSEMBLAGES OF SAN JUAN RIVER

SECONDARY CHANNELS

1991 – 1997

LITERATURE CITED

LITERATURE CITED

Baxter, G.T. and J.R. Simon. 1970. Wyoming Fishes. Bulletin No. 4, Wyoming Game and Fish Department, Cheyenne.

Becker, G.C. 1986. Fishes of Wisconsin. The University of Wisconsin Press, Madison.

Bliesner, R. and V. Lamarra. 1995. San Juan River habitat studies, 1994 annual report. San Juan River Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Bliesner, R. and V. Lamarra. 1996. San Juan River habitat studies, 1995 annual report. San Juan River Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Bliesner, R. and V. Lamarra. 2000. San Juan River habitat studies. San Juan River Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Brooks, J.E., M.J. Buntjer, and J.R. Smith. 2000. Nonnative species interactions: Management implications to aid in recovery of the Colorado squawfish, *Ptychocheilus lucius*, and razorback sucker, *Xyrauchen texanus* in the San Juan River, Colorado-New Mexico-Utah. San Juan River Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Brandenburg, W.H. and K.B. Gido. 1999. Predation by nonnative fish on native fishes in the San Juan River, New Mexico and Utah. The Southwestern Naturalist 44: 392-394.

Carlander, K.D. 1969. Handbook of freshwater fishery biology, Vol. 1. The Iowa State University Press, Ames.

Childs, M.R., R.W. Clarkson, and A.T. Robinson. 1998. Resource use by larval and early juvenile native fishes in the Little Colorado River, Grand Canyon, Arizona. Transactions of the American Fisheries Society 127: 620-629.

Conklin, D.J., Jr., S.P. Canton, J.W. Chadwick, and W.J. Miller. 1996. Habitat suitability curves for selected fish species in the central Platte River, Nebraska. Rivers 5: 250-266.

Eder, S. and C.A. Carlson, 1977. Food habits of carp and white suckers in the South Platte and St. Vrain rivers and Goosequill Pond, Weld County, Colorado. Transactions of the American Fisheries Society 106: 339-346.

Fader, S.C., Z Yu, and J.R. Spotila. 1994. Seasonal variation in heat shock proteins (hsp70) in stream fish under natural conditions. Journal of Thermal Biology 5: 335-341.

Gale, W.F. 1986. Indeterminate fecundity and spawning behavior of captive red shiner—fractional, crevice spawners. Transactions of the American Fisheries Society 115: 429-437.

Gido, K.B., D.L. Propst, and M.C. Molles, Jr. 1997. Spatial and temporal variation of fish communities in secondary channels of the San Juan River, New Mexico and Utah. Environmental Biology of Fishes 49: 417-434.

Gido, K.B. and D.L. Propst. 1999. Habitat use and association of native and nonnative fishes in the San Juan River, New Mexico and Utah. Copeia 1999: 321-332.

Greger, P.D. and J.E. Deacon. 1988. Food partitioning among fishes of the Virgin River. Copeia 1988: 314-323.

Holden, P.B. and C.R. Stalnaker. 1975. Distribution and abundance of mainstream fishes of the middle and upper Colorado River basins, 1967-1973. Transactions of the American Fisheries Society 104: 217-231.

Hubbs, C. 1996. Geographic variation in life history traits of *Gambusia* species. pp. 1-21. In G.P. Garrett and A.M. Sudyka (eds.). Proceedings of the Desert Fishes Council, 1995 Symposium XXVII.

Larson, R.D. and D.L. Propst. 1999. Distribution, abundance, and food habits of piscivorous fishes inhabiting the Pecos River between Sumner Dam and Brantley Reservoir, New Mexico. New Mexico Department of Game and Fish, Santa Fe.

LaRivers, I. 1962. Fishes and fisheries of Nevada. Nevada State Fish and Game Commission, Carson City.

Maddux, H.R. and W.G. Kepner. 1988. Spawning of bluehead sucker in Kanab Creek, Arizona (Pisces: Catostomidae). The Southwestern Naturalist 33: 364-365.

Matthews, W.J. and L.G. Hill. 1979. Age-specific differences in the distribution of red shiners, *Notropis lutrensis*, over physiochemical ranges. American Midland Naturalist 101: 366-372.

Marsh, P.C. and M.E. Douglas. 1997. Predation by introduced fishes on endangered humpback and other native species in the Little Colorado River, Arizona. Transactions of the American Fisheries Society 126: 343-346.

McAda, C.W. and R.S. Wydoski. 1983. Maturity and fecundity of the bluehead sucker, *Catostomus discobolus* (Catostomidae), in the upper Colorado River basin. The Southwestern Naturalist 28: 120-123.

Minckley, W.L. 1973. Fishes of Arizona. Arizona Game and Fish Department, Phoenix, AZ.

Minckley, W.L. and G.K. Meffe. 1986. Differential selection by flooding in stream fish communities of the American Southwest. pp. 93-104 in W.J. Matthews and D.C. Heins (eds.). Community and evolutionary ecology of North American stream fishes. University of Oklahoma Press, Norman.

Moyle, P.B. 1976. Inland fishes of California. University of California, Berkeley.

Muth, R.T. and T.P. Nesler. 1993. Associations among flow and temperature regimes and spawning periods and abundance of young of selected fishes, lower Yampa River, Colorado, 1980-1984. Colorado State University Larval Fish Laboratory Contribution No. 58.

Pellett, T.D., G.J. van Dyck, and J.V. Adams. 1998. Seasonal migration and homing of channel catfish in the lower Wisconsin River, Wisconsin. North American Journal of Fisheries Management 18: 85-95.

Platania, S.P. 1990. Biological summary: San Juan River ichthyological study, New Mexico-Utah, 1987-1989. U.S. Bureau of Reclamation, Salt Lake City, UT.

Rehder, D.D. 1959. Some aspects of the life history of the carp, *Cyprinus carpio*, in the Des Moines River, Boone County, Iowa. Iowa State Journal of Science 34: 11-26.

Ricklefs, R.E. 1979. Ecology. Chiron Press, Inc., New York, NY.

Ryden, D.W. and F.K. Pfeifer. 1995. Adult fish community monitoring on the San Juan River, 1994 annual progress report. San Juan River Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Ryden, D.W. and F.K. Pfeifer. 1996. Adult fish community monitoring on the San Juan River, 1995 annual progress report. San Juan River Recovery Implementation Program, U.S. Fish and Wildlife Service, Albuquerque, NM.

Sokal, R.R. and Rohlf. 1981. Biometry. W.H. Freeman & Co., San Francisco, CA.

Tyus, H.M., B.D. Burdick, R.A. Valdez, C.M. Haynes, T.A. Lytle, and C.R. Berry. 1982. Fishes of the upper Colorado River basin: Distribution, abundance, and status. pp. 12-70. In W.H. Miller, H.M. Tyus, and C.A. Carlson (eds.). Fishes of the upper Colorado River system: Present and future. American Fisheries Society, Bethesda, MD.

Tyus, H.M. and N.J. Nikirk. 1990. Abundance, growth, and diet of channel catfish, *Ictalurus punctatus*, in the Green and Yampa rivers, Colorado and Utah. The Southwestern Naturalist 35: 188-198.

U.S. Geological Survey (USGS). 1991 et seq. Water Resources Data New Mexico. U.S. Geological Survey, Albuquerque, NM.

Zar, J.H. 1984. Biostatistical analysis. Prentice_Hall, Inc. Englewood Cliffs, NJ.